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Description

This invention relates generally to well bore measurement tools and more particularly, but not by way of limitation, to a fracture orientation caliper tool mounted between two interlockable packers.

In taking measurements within a well bore, it is known to set two seals, referred to as packers, in the well at the upper and lower positions of the formation to be fractured, with a measuring device therebetween. A pressurized fracturing fluid is then injected between the set packers through a tubing or pipe string on which the packers are carried into the hole. Such procedure can be used either when the well bore is lined with a casing or when the well bore is unlined (referred to herein as an open well bore, or the like).

The measuring device is used with the interlockable packers to determine the direction of a fracture that is created by a hydraulic fracturing process or treatment which is applied between the interlocked packers. The measuring device is usually referred to as a caliper, of which there are various types known to the art.

One example of a prior art well bore measurement tool is shown in US-A-4251921, which discloses such a tool comprising: a support member, at least one pivot arm pivotally connected to the support member; and at least one sensor means for sensing a movement of said pivot arm when said sensor means is coupled to said pivot arm, said sensor means including displacement measurement means, connected to said support member for generating a signal in response to a sensed movement of said pivot arm.

The present invention relates to an improved measurement tool of the above described form which is , characterized in that said sensor means further includes connecting means for releasably connecting said pivot arm to said displacement measuring means, and actuating means, connected to said support member, for actuating said connecting means to connect said pivot arm to said displacement measuring means.

With this arrangement, the sensor means can be selectively engaged with and disengaged from the displacement measuring tool and in particular can be engaged when the arms are pivoted against the wall of the borehole to measure variations in the size thereof.

Further features and advantages of the present invention will be readily apparent to those skilled in the art when the following description of the preferred embodiments is read in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic illustration of a double or dual packer/caliper assembly depicting a preferred embodiment of the present invention.

FIGS. 2A-2F form a partial sectional view of an upper packer section which can be used in the assembly illustrated in FIG. 1 and which includes a preferred embodiment of a lock by which the two packers of the FIG. 1 assembly can be interlocked.

FIG. 3 is a sectional end view of a locking mandrel of the lock of the preferred embodiment as taken along line 3-3 shown in FIG. 2B, but without the other structures shown in FIG. 2B.

FIG. 4 is a plan view of a portion of a latch member of the lock of the preferred embodiment.

FIGS. 5A-5B illustrate the preferred embodiment structure for mounting the caliper between the packers.

FIG. 6 is an elevational illustration of a basic structure for implementing one preferred embodiment of the caliper of the present invention.

FIG. 7 is a sectional view of the principal portion of another preferred embodiment of the caliper.

FIG. 8 is a detailed view of a latch mechanism in the preferred embodiments of the caliper.

FIG. 9 depicts the limit gearing of a drive mechanism of the preferred embodiments of the caliper.

FIG. 10 is an enlarged view of a portion of a clutch and spider coupling sub-assembly as shown in Fig. 7.

FIG. 11 is a partial end view of a spider arm, to which pawls are connected, and a clutch roller member engaged by the pawls.

The preferred embodiment of the present invention will be described with reference to a dual packer assembly 2 disposed in an open well bore 4. This construction is schematically illustrated in FIG. 1 (although not so illustrated because of the schematic nature of FIG. 1, the bore 4 has an irregular side wall, not a smooth side wall, known in the art).

The dual packer assembly 2 illustrated in FIG. 1 includes a bottom or lower packer section 6 of conventional design (such as the lower end of a Halliburton Services No. 2 NR packer assembly). Spaced above the lower packer section 6 is a top or upper packer section 8 which includes at least part of a conventional upper packer assembly (such as the top portion of a Halliburton Services No. 2 NR packer assembly), but which also incorporates the novel and improved lock by which the packers can be interlocked in the present invention.

Shown mounted within a slotted sleeve 9 extending between the packer sections 6, 8 is a caliper tool 10 which is also part of the present invention. Although a caliper tool generally exemplifies a device whose proper operation can require that the top packer section 8 not be displaced when the fracturing pressure, applied to the volume

of the well bore 4 which is between the packer sections and in which the caliper tool 10 is disposed, exerts a force that exceeds any downwardly acting weight of the pipe on which the packer assembly 2 and the caliper tool 10 are lowered into the well, and the force of any hydrostatic head acting downwardly on the upper packer section 8, the caliper tool 10 of the preferred embodiment is constructed and mounted so that at least some movement of the packers is tolerated. However, the use of a caliper with the packers does generally illustrate the need for the lock of the present invention by which the upper packer section 8 can be effectively locked to the lower packer section 6, which is anchored by an anchor pipe 12 into the bottom or the side of the well bore 4, to prevent upward movement of the packer of the section 8. Even used alone the packers may need to be interlocked to prevent unseating of the top packer, which unseating could possibly allow the fracturing fluid to escape to the surface where a hazardous situation could result. The preferred embodiment of this lock is illustrated within the downhole apparatus shown in FIGS. 2A-2F.

The downhole apparatus illustrated in FIGS. 2A-2F in conjunction with the lock of the present invention is an example of the upper packer section 8. This apparatus includes an inner tubular member 14 and an outer tubular member 16, both of which include a plurality of components. The inner member 14 is slidable relative to the outer member 16, but these two members can be locked together by a lock 18 of the present invention.

The inner tubular member 14 of the upper packer section 8 is characterized in the preferred embodiment as a mandrel assembly including a packer mandrel 20 (FIGS. 2C-2F) and a locking mandrel 22 (FIGS. 2A-2C). The packer mandrel 20 is a cylindrical tube of conventional design having a lower externally threaded end for engaging a lower adapter 24 of a conventional type used for connecting (through the caliper tool 10 in the FIG. 1 configuration) to the lower packer section 6 anchored on the bottom or in the side wall of the well bore 4 by the anchor pipe 12. The packer mandrel 20 has an internally threaded throat at its other end for threadedly coupling with an externally threaded end of the locking mandrel 22, which locking mandrel 22 forms part of the lock 18, and will be described hereinbelow.

The outer tubular member 16 is characterized in the preferred embodiment as an upper packer carrying assembly having a packer 26 (FIGS. 2D-2E) connected (for example by a bolting fastening means including nut and bolt combination 28 shown in FIG. 2D) to a packer carrier sleeve. The packer carrier sleeve includes a packer retaining collar 30, to which the packer 26 is fastened, and a connecting sleeve 32, to which the retaining collar 30 is connected by a quick change coupling 34 (FIGS. 2B-2D). The packer carrier sleeve also includes a locking sleeve 36 (FIGS. 2A-2C) threadedly connected to connecting sleeve 32 and which forms part of the lock 18.

The packer 26 is made of a composition (e.g., an elastomer) of a type known in the art, and annular shape with a hollow interior in which the packer mandrel 20 is slidably received. Providing lower support to the packer 26 are a packer support 38 (shown in FIG. 2E as being splined with the packer mandrel 20), a rubber packer shoe 40, a packer shoe support 42 and a coupling collar 44 threadedly interconnecting the shoe support 42 with the lower adapter 24 (FIGS. 2E-2F). These elements are of conventional design and thus will not be further described.

The packer retaining collar 30, the connecting sleeve 32, and the quick change coupling 34 are also of conventional designs and will not be particularly described here. It will be noted, however, that the coupling between the packer retaining collar 30 and the connecting sleeve 32 includes a known type of seal 46 retained between the packer retaining collar 30 and the connecting sleeve 32 adjacent to the packer mandrel 20, as shown in FIG. 2D. Additionally, the connecting sleeve 32 is shown splined to the packer mandrel 20, identified by the reference numeral 48 in FIG. 2C.

The outer tubular member 16 connects at its upper end to an upper adapter 50 (FIG. 2A) of conventional design, for connecting to the tubing or pipe string (not shown) on which the dual packer assembly 2, and the caliper tool 10 are run into the open well bore 4. The upper adapter 50 carries a seal 52 for providing a sliding fluid seal between the upper adapter 50 and the locking mandrel 22.

The lock 18 includes not only the aforementioned locking mandrel 22 and the locking sleeve 36, but also a latching mechanism 54. Each of these elements will described with reference to FIGS. 2A-2C, 3 and 4.

The locking mandrel 22 is a means for connecting part of the lock 18 with the packer mandrel 20 inside the portion of the upper packer section 8 defining the outer tubular member 16. The locking mandrel 22 is an elongated member having a cylindrical inner surface 56 defining a longitudinal channel 58 which extends axially throughout the length of the locking mandrel 22.

The mandrel 22 also has a cylindrical protuberant portion 60 extending radially outwardly from the main body. Milled or otherwise defined in the protuberant portion 60 are four cavities 62, 64, 66, 68 (FIGS. 2B and 3) which extend through the outer surface of the protuberant portion 60 and into the protuberant portion 60 transversely to the length of

the mandrel 22. Associated with each of the four cavities are two slots extending longitudinally from opposite ends of the respective cavity. The two slots associated with the cavity 62 are identified in FIG. 2B by the reference numerals 70, 72, and for cavities 64, 66, 68, slots 74, 76, 78, respectively, corresponding to the slot 72 of cavity 62, see FIG. 3. The cavities 62, 64, 66, 68 are disposed in two pairs of diametrically opposed cavities, whereby one pair includes the cavities 62, 66 and the other pair includes the cavities 64, 68. These cavities and slots open towards, or face the locking sleeve 36.

The locking mandrel 22 also includes a cylindrical outer surface 80 defining a lower sealing surface engaged by a seal 82 (FIG. 2C) retained in a recess 84 of the locking sleeve 36. The diameter of the surface 80 is less than the outermost diameter of the protuberant portion 60 and a radially extending annular shoulder 86 is defined therebetween.

The locking mandrel 22 has another cylindrical outer surface 88, which extends longitudinally from the end of the protuberant portion 60 opposite the end thereof from which the surface 80 extends. The surface 88 has the same diameter as the surface 80, and a radially extending annular shoulder 90 is defined between the surface 88 and the outermost portion of the protuberant portion 60. The outer surface 88 defines an upper sealing surface engaged by the seal 52 carried by the upper adapter 50. The seal 52 and the seal 82 are the same size so that a hydraulically balanced seal is created between the locking mandrel 22 and the locking sleeve 36 on opposite sides of the protuberant portion 60.

The protuberant portion 60 can travel longitudinally, or axially, within a volume 91 defined between a surfaces of the locking mandrel 22, and inner surface 92 of the locking sleeve 36 and by the inner surface 92 of the locking sleeve 36 being offset radially outwardly from an inner surface 94 of the locking sleeve 36. This offset is established across a radial annular shoulder 95 which faces the shoulder 86 of the locking mandrel 22. The volume 91 also extends between the longitudinally spaced circumferential seals 52, 82. The locking sleeve 36 has a cylindrical outer surface 96 and a threaded outer cylindrical surface 98 radially inwardly offset from the surface 96 for engaging an internal thread of the connecting sleeve 32.

Defined along the inner surface 92 is a locking sleeve engagement surface 100 comprising grooves or serrations or teeth defining engagement means for interlocking with cooperating elements of a latch member forming part of the latching mechanism 54. The locking sleeve engagement surface 100 is not coextensive with the length of the surface 92, so that the latching mechanism 54 is longitudinally movable between a longitudinally located unlatched, or disengagement position, located closer to the shoulder 95 than to the opposite end of the volume 91 and adjacent a radial annular surface 101 of the upper adapter 50, and a longitudinally located latchable or engagement position, wherein at least part of the latching mechanism overlies at least a portion of the locking sleeve engagement surface 100.

The latching mechanism 54 of the preferred embodiment includes latch member means, slidably disposed in at least one of the cavities 62, 64, 66, 68, for engaging the packer carrying sleeve assembly (specifically, the locking sleeve engagement surface 100 in the preferred embodiment) when the latch member means is moved to the aforementioned longitudinal engagement position and then to a radially located latched or engagement position. The latching mechanism 54 also includes actuating pressure communicating means, disposed in the tubular member on which the latch member means is mounted, for communicating an actuating pressure to the latch member means so that the latch member means moves towards the other tubular member, and into the radial engagement position, in response to the actuating pressure. The latching mechanism 54 also includes biasing means, connected to the tubular member on which the latch member means is mounted, for exerting a biasing force against the latch member means in opposition to a force exerted on the latch member means by the actuating pressure so that the latch member means is biased away from the other tubular member and thus towards a radial disengagement position which is out of engagement with the locking sleeve engagement surface 100 even though the locking member means even partially overlies the engagement surface 100 and is thus at a longitudinal latchable or engageable position. Thus, this biasing force tends to move the latch member means deeper into its respective cavity. The latching mechanism 54 still further includes hydrostatic pressure communicating means, disposed in the tubular member on which the latch member means is not mounted, for communicating a hydrostatic pressure to the latch member means so that a force exerted by the hydrostatic pressure is applied to the latch member means in opposition to a force exerted on the latch member means by the actuating pressure.

The latch member means of the preferred embodiment includes four latch members, each disposed in a respective one of the cavities 62, 64, 66, 68. Because each of these latch members is identical, only a latch member 102 principally shown in FIG. 2B will be described. The latch member 102 includes a gripping member or means

104 for defining a latch member engagement surface 106 (see also FIG. 4) facing the inner surface 92 of the locking sleeve 36. The gripping means 104 of the preferred embodiment is constructed of an oblong carrier block 108 and a plurality of gripping teeth 110 defined in the preferred embodiment by carbide inserts retained in the carrier block 108 at oblique angles thereto to give a tilted configuration to the carbide inserts which facilitates their ability to bite or grip into the locking sleeve engagement surface 100 of the locking sleeve 36. The teeth 110 are received along a rectangular planar surface 111 of the carrier block 108, and they define a plurality of protuberances extending from the surface of the carrier block 108. Milled or otherwise defined in opposite ones of the curved ends of the oblong carrier block 108 are respective recesses 112, 114. The recess 112 has a curved lower surface 116. Parallel planar surfaces 118, 120 extend from opposite edges of the surface 116. The recess 114 has a curved lower surface 122 and parallel planar surfaces 124, 126 extending from opposite edges of the surface 122.

The latch member 102 also includes seal means 128, detachably connected to the carrier block 108, for providing a sliding seal between the latch member 108 and the inner side walls of the cavity 62 in which the latch member 102 is disposed. The seal means 128 includes a seal support member 130 having an oblong configuration similar to that of the carrier block 108, and the shape of the cavity 62. A peripheral groove 132 is defined around the perimeter of the seal support member 130. The groove 132 receives a seal assembly 134 comprising an O-ring, or other suitable fluid member, and a seal back-up ring which reduces the friction of the movable seal and reinforces the primary seal ring against high pressure differentials which may exist across the sealing structure.

The seal support member 130 is connected to the carrier block 108 by a suitable connector means, whereby the two are releasably connected to enable the carrier block 108 to be released from the seal support member 130, for example, when the latch member engagement surface defined by the gripping teeth 110 is worn out and is to be replaced. In the preferred embodiment the connector means includes a dovetail tenon 136, protruding from a central portion of the seal support member 130, and a mortise 138, defined centrally along and transversely across a surface of the carrier block 108 for slidably receiving the dovetail tenon 136.

The components of the latch member 102 define a slidable body which is movable within the cavity 62. Corresponding components define latch members in the cavities 64, 66, 68 for simultaneous slidable movement with the latch member 102. This movement occurs in response to an actuating pressure provided through the tubing or pipe string from the surface and the channel 58 of the locking mandrel 22 and through respective actuating pressure communicating means to the cavities 62, 64, 66, 68. As each of the communicating means is identical, only the one associated with the cavity 62 will be described.

The actuating pressure communication means communicates a hydraulic pressure from the axial channel 58 into the cavities 62, 64, 66, 68 of the locking mandrel 22. This pressure exerts a force against the latch member 102, and the other latch members, which when sufficiently strong, moves the latch members radially outwardly so that at least portions of the engagement surfaces thereof interlock with at least a portion of the locking sleeve engagement surface 100 of the locking sleeve 36 when these portions are radially aligned. This radial alignment is achieved after the packers have been set as will be described below.

To provide communication to the cavity 62, the actuating pressure communicating means associated with the cavity 62 includes two holes 140, 142 defined by respective transverse walls of the locking mandrel 22. These walls extend between the channel 58 and the cavity 62. The actuating pressure is communicated through these holes from the fracturing fluid pumped down through the central channel extending through the entire upper packer section 8 into the open well bore 4 volume encompassed between the spaced packers of the lower and upper packer sections 6, 8.

The biasing means of the latch mechanism 54 includes two spring members for each of the latch members. As the spring members are identical, for each latch member, therefore only the two associated with the latch member 102 shown in FIG. 2B will be described. These spring members are identified by the reference numerals 144, 146. The spring member 144 has a support portion 148 and an engagement portion 150 extending at an obtuse angle from the support portion 148. The spring member 144 is made of a resilient material so that the engagement portion 150 can bend relative to the support portion 148, but with a resulting biasing force being created tending to return the engagement portion 150 to its rest position shown in FIG. 2B. This action provides a biasing force which acts in opposition to the direction of the hydraulic actuating pressure applied through the holes 140, 142 and thereby tends to move the latch member 102 deeper into the cavity 62. This acts as a return force when the actuating pressure is removed.

The support portion 148 is received in the slot 70, and the engagement portion 150 extends as a spring finger into the recess 112 of the latch member 102. The spring member 144 is secured in the slot 70 by suitable connecting means which

achieves the aforementioned construction wherein the end of the spring member 144 defined by the engagement portion 150 overhangs the cavity 62 and engages the carrier block 108 within its recess 112 to exert a radially inwardly directed force on the block 108 and thus on the overall latch member 102. This connecting means comprises in the preferred embodiment a spring backup, or support member, 152 adjacent the support portion 148 of the spring member 144, and a screw, or bolt, 154 extending through holes defined in the support portion 148 and the spring support member 152 and into a radially extending threaded bore extending from the slot 70 into the protuberant portion 60 of the locking mandrel 22.

The spring member 146 is constructed and situated similarly to the spring member 144, except that it has a support portion 156 which is secured in the slot 72 by a spring support member 158 and a screw or bolt 160. This allows an engagement portion 162 of the spring member 146 to extend into the recess 114 of the latch member 102. Therefore, the spring member 146 extends in an opposite direction towards the spring member 144 and in a manner so that the engagement portion 162 overhangs the cavity 62 and engages the carrier block 108 to exert a radially inwardly directed force on the block 108.

The biasing means also includes a retaining ring 164 freely disposed between the screws or bolts 154, 160 and partially overlying the spring members 144, 146 and the carrier block 108. The ring 164 acts as a safety backup to prevent the spring members 144, 146 from becoming too outwardly extended.

The hydrostatic pressure communicating means of the latching mechanism 54 includes four radial passages defined through the locking sleeve 36 so that a pressure existing externally of the locking sleeve 36 is communicated internally thereof to exert a radially inwardly directed force on the latch member 102 and, in particular, on the carrier block 108 thereof. These four passages are equally spaced around the circumference of the locking sleeve 36 so that only one, identified as a hole 166, is shown in FIG. 2B. In the preferred embodiment each of these holes has a one-half inch diameter; however, any suitable size hole can be used. The hole 166, and its three counterparts, extend radially through the locking sleeve 36 along the shoulder 95 defined between the offset inner surfaces 92, 94. This provides communication passages for allowing the hydrostatic pressure existing outside the upper packer section 8 and above the packer 26 to be communicated into the volume 91 within the locking sleeve 36 between the seals 52, 82. These holes also allow the hydraulic chamber or volume 91 to fill with fluid as the dual packer assembly 2 is run in the hole, thereby balancing the internal and external pressures across the latch members during this time.

To use the lock, the packer assembly 2 is attached to a tubing or pipe string (not shown) and run into the well bore 4 in a manner known in the art. When the dual packer assembly 2 is at the appropriate location, the packer 26 and the packer of the lower packer section 6 are set, also in a manner known in the art. In running this structure into the well bore 4, the inner and outer tubular members of the upper packer section 8 are situated as shown in FIGS. 2A-2F; however, when the packers are set, relative movement between the inner and outer tubular members occurs so that the latch member 102, and the other three latch members disposed in the cavities 64, 66, 68, have at least portions of their latch member engagement surfaces radially aligned with at least a portion of the locking sleeve engagement surface 100. At this time, but prior to a sufficient actuating pressure being applied down through the tubing or pipe string and into the channel 58 of the locking mandrel 22, the spring members of the biasing means are holding the respective latch members in their radial unlatched positions, as illustrated by the position of the latch member 102 in FIG. 2B. These latch members are also held in these unlatched radial positions by the hydrostatic pressure existing in the annulus between the locking sleeve 36 and the surface of the well bore 4. This hydrostatic pressure is exerted on the latch members by being communicated thereto through the radial passages of the hydrostatic pressure communicating means (e.g., the hole 166). Locating the lock 18 above the top packer 26 isolates and limits the outside, or external, force acting radially inwardly on the latch members to the hydrostatic pressure.

When the hydraulic lock 18 is to be actuated, whereby the latch members are moved into their engagement positions with the gripping teeth of the latch members interlocking with the locking sleeve engagement surface 100, a fluid is flowed down the tubing or pipe string into the channel 58 and pressurized until a sufficiently strong radially outwardly directed force, which exceeds the forces exerted by the spring members and the hydrostatic pressure is exerted through the actuating pressure communicating means (e.g., the holes 140, 142) on each of the latch members. The application of this radially outwardly directed force simultaneously moves each of the latch members radially outwardly to lock the inner tubular member 14 to the outer tubular member 16. This in effect locks the packer 26 to the lower packer section 6 because the inner tubular member 14 is connected to the lower packer section 6 through the lower adapter 24. As long as the tubing pressure exceeds the

hydrostatic pressure and the biasing force of the spring members, the latch members lock into the outer housing of the upper packer section 8, thereby preventing upward movement of the top packer 26. Once the fracturing or other actuating pressure is removed, the latch members are returned to their original radially disengaged positions by the hydrostatic pressure and the retracting spring members of the biasing means.

As indicated generally in FIG. 1, mounted between the lower packer section 6 and the upper packer section 8 is the caliper tool 10. The preferred embodiment of a means for mounting the caliper tool 10 between the two packer sections is illustrated in FIGS. 5A-5B. Broadly, this mounting is achieved by retainer means for retaining the caliper 10 between the lower and upper packers so that the caliper is transportable into the well bore with the two packers but so that the two packers are longitudinally movable relative to the caliper tool when the caliper tool engages the side wall of the well bore 4.

This retainer means in the preferred embodiment includes the slotted sleeve 9 shown in FIGS. 5A-5B as having a cylindrical wall 200 having an upper end adapted for connecting with the upper packer section 8 and having a lower end adapted for connecting with the lower packer section 6 through a bypass valve section 202 (directional references, such as "upper" and "lower," are made with regards to orientations shown in the drawings and to normal orientation of the caliper tool 10 in a vertical well bore). Near the upper end of the wall 200 there is defined one or more ports 204 through which fluid can flow to or from the interior hollow region of the upper packer section 8 and to or from an upper cavity 206 defined within the slotted sleeve 9 by the portion of the wall 200 through which the ports 204 are defined and by an annular wall 208. Defined through an intermediate portion of the wall 200 are a plurality of slots 210 through which engagement implements of the caliper tool 10 extend as will be more particularly described hereinbelow. The slots 210 are spaced circumferentially around the wall 200 as is apparent in FIG. 5A.

Mounted within a cavity 212 defined in the slotted sleeve 9 below the wall 208 is an inner spring housing 214, which has a lower end (not shown) connected to the anchor pipe to which the lower packer section 6 is connected. The housing 214 has a cylindrical wall 216 through which a plurality of slots 218 are defined. The housing 214 is held within the slotted sleeve 9 so that the longitudinally extending slots 218, 210 are radially aligned so that the extendible implements of the caliper tool 10 can be extended radially therethrough.

The wall 216 terminates at its upper end in an end wall 220 through which an aperture 222 is defined for providing fluid communication between the cavity 212 of the slotted sleeve 9 and a cavity 224 of the spring housing 214. It is within the cavity 224 that the caliper tool 10 is received. Extending axially from the end wall 220 is a wet connector adapter 226 having a cylindrical shape defining a neck within which is defined a throat. The throat receives the wet connector, or an electrical coupling thereof, in a manner known in the art, to make an electrical connection between a wireline and the caliper tool 10.

The lower end of the cavity 224 of the housing 214 is defined by a radial wall 228. The wall 228 defines not only the bottom of the cavity 224, but also the top of a cavity 230 in which a magnetometer 232 is disposed. The magnetometer 232 is one type of device by which the position of the caliper tool 10 relative to magnetic north can be determined. Other position locating instruments such as an inclinometer or a gyroscope can also be used. Alternatively, a pipe tally can be made.

Contained within the cavity 224 of the housing 214 is the caliper tool 10, which is specifically retained within the cavity 224 by an upper spring 234 and a lower spring 236. The spring 234 extends between the inner surface of the wall 220 and a top surface of the caliper tool 10, and the spring 236 extends between a lower surface of the caliper tool 10 and an upper surface of the wall 228 as shown in FIGS. 5A-5B. Thus, the springs 234, 236 and the caliper 10 are held within the housing 214 which is in turn retained within the slotted sleeve 9 connected to the packer sections 6, 8. The springs 234, 236 effect a free-floating mounting construction so that the caliper 10 is free to move longitudinally within the housing 214 which thereby allows movement relative to the packer sections 6, 8. In the preferred embodiment the springs 234, 236 allow approximately one or two inches (2.5 to 5.1cm) of longitudinal movement. This is important in the preferred embodiment of the present invention wherein the caliper 10 is directly locked to the well bore 4 once it is placed in use, which locked engagement is not to be disturbed even if the interlocked packer sections 6, 8 should move. The springs 234, 236 also provide cushioning for the caliper tool 10 on its trips into and out of the well bore.

The bypass valve section 202 partially shown in FIG. 5B is of a suitable type known in the art. It includes at least one port 238 through which fluid can flow when the valve of the section 202 is open. When the valve is open, this allows fluid flow between the upper port or ports 204 of the slotted sleeve 9 and the port 238 of the bypass valve section 202 whereby the fluid flows around the

caliper tool 10 and its spring carrier section.

The caliper tool 10 illustrated in FIGS. 5A-5B is only partially shown for purposes of simplicity. The tool 10 is shown as including an upper section 240 in which the electronics and the drive motor are supported. Also supported by the section 240 are transducers which respond to the movement of the radially extendible implements of the tool 10. Two of these implements, which are connected at their upper ends to the upper section 240, are identified in FIG. 5A by the reference numeral 242. Other transducers which can be included within the upper section 240 are pressure transducers and temperature transducers and any other suitable ones which can be accommodated within the size constraints of such a downhole apparatus. The extendible members 242 are connected at their lower ends to a lower section 244 which forms part of the drive means for moving the extendible members 242 with independent forces. Force indicating transducers can also be included within the section 244 for indicating the magnitudes of the independent forces applied to each of the extendible members 242. Not shown in FIG. 5A, but part of the preferred embodiment of the caliper tool 10, is a coupling mechanism by which each of the extendible members 242 is connectible to a respective movement detecting sensor contained within the upper section 240. The components of each of these sections will be described with reference to FIGS. 6-11.

The embodiment shown in FIG. 6 has the outer coverings of the upper section 240 and lower section 244 removed to show the general internal constructions. Also removed is the coupling mechanism for coupling the members 242 to the sensors and this coupling mechanism is shown in the embodiment of FIG. 7. The upper section 240 has a plurality of longitudinal support rods 246. Connected to these support rods 246 are two lateral support plates 248, 250 which are longitudinally spaced from each other. An upper end lateral plate 252 is connected to the ends of the rods 246 opposite the plate 248. The rods 246 are spaced near the outer perimeter of the plates 248, 250, 252 so that the working components of the upper section 240 can be mounted interiorly of the rods 246 and between the spaced plates 248, 250, 252. These working components include an electric motor 254 of a suitable type known to the art, such as a standard well logging tool motor. Also mounted in this region are printed circuit boards containing suitable circuitry for conditioning the various electrical signals applied to or generated in the present invention. A motor control circuit for controlling the motor 254 is also included. These circuits are not shown or further described because they are of type known to those skilled in the art for performing the functions of the present invention.

The lower section 244 of the embodiment shown in FIG. 6 includes a carriage 255 having an outer covering 256 (shown in FIG. 5A) and end support plates 258, 260 between which connecting rods 262 extend to longitudinally space and support the end plates 258, 260. The end plates 258, 260 have a plurality of longitudinally aligned apertures defined therethrough near their outer perimeters. Spring guide rods 264 are slidably disposed through the apertures. There are six such pairs of apertures and six such spring guide rods in the preferred embodiment to correspond to the six extendible members 242 used in the preferred embodiment. The top end of each of the rods 264 is pivotally connected to the end of a respective one of the extendible members 242 as shown in FIG. 6.

Each of the spring guide rods 264 has a retaining collar 266 for retaining a respective spring 268 between the support plate 260 and the collar 266. The springs 268 are compressed in response to suitable movement of the carriage which occurs through a ball screw coupling mechanism 270 which couples the carriage 255 to the motor 254.

In response to longitudinal movement of the carriage 255 of the lower section 244, each of the extendible members 242 is radially moved inwardly or outwardly depending upon the longitudinal direction of movement of the carriage. Each of the members 242 defines a pivot arm comprising a longer strut or arm section 272 and a shorter strut or arm section 274 which are pivotally connected at a pivot joint 276. The end of the strut 272 opposite the pivot joint 276 is pivotally connected to a retaining plate 278 of the upper support section 240 at a pivot joint 280. The end of the strut 274 opposite the joint 276 is connected at a pivot joint 282 to a respective portion of the support plate 258. These pivot connections are of any suitable type, such as a pin and clevis type of coupling where a bifurcated portion is pinned to a retaining tab received between the bifurcations.

A more detailed description of at least some of the foregoing elements and the functions of these elements will be more particularly described with reference to the embodiment shown in FIGS. 7-11, which embodiment shows a more detailed construction than shown in the FIG. 6. It is to be understood that the embodiments shown in FIGS. 6 and 7-11 have many similar components and are functionally identical. Common or similar items between the FIG. 6 and FIG. 7 embodiments are indicated by like reference numerals.

The upper section of the embodiment shown in FIG. 7 includes a support framework similar to that shown in FIG. 6. It is also shown in FIG. 7 to be enclosed in a covering or housing 284. The hous-

ing 284 is positioned adjacent the housing 214. The housing 284 is connected to the support wall, or bulkhead, 278 by screws or other suitable means.

Attached into a beveled aperture 285 defined axially in the top wall of the housing 284 is a wet connector adapter 287. The adapter 287 includes a beveled plug 289 having a seal member 291 retained thereon. The plug is secured in the beveled aperture 285 by a cylindrical threaded receiving sleeve 293 threadedly connected into the aperture 285. The sleeve 293 receives a wet connector member 295 when it is lowered into the well bore at the end of a wireline. In the preferred embodiment the wet connector tool from which the member 295 extends is of any suitable type, such as of a type used by Welex, but adapted for use with the present invention. One feature of such an adaptation could be to use a slip joint construction intermediate the wet connector tool and the member 295. Such a slip joint would accommodate the approximately seven inches (17.8 cm) of vertical displacement that. can be encountered in setting the upper packer section of the preferred embodiment.

The upper section of the embodiment shown in FIG. 7 includes the motor 254 mounted on a support bracket 286 which is connected to the support plate 248 by screws, one of which is identified by the reference numeral 288. The shaft of the motor is coupled to a coupling or connecting rod 290 which connects the motor shaft to a ball screw shaft 292 of the ball screw coupling mechanism 270. Associated with the drive shaft of the motor 254 and the connecting shaft 290 is a gear 294 shown in FIG. 9. The gear 294 is associated with four other gears 296, 298, 300, 302 to provide a gear drive sized to count twenty-two rotations of the ball screw shaft 292 in the preferred embodiment. When these twenty-two revolutions have occurred, a pin 304 on the gear 302 engages an upward direction limit switch of limit switches 306. This deactivates the motor 254 from further driving the ball screw shaft 292. These gears and the limit switch are located in a compartment or region 308 shown in FIG. 7 to be disposed between the longitudinally spaced plates 248, 250. A roller bearing 310 and a thrust bearing 312 are used to provide suitable support to the shaft 290. These bearings are supported in oppositely facing cavities axially defined in the bulkhead 278. This is an alternative construction of the bulkhead from the thinner one shown in the FIG. 6 embodiment. In the FIG. 6 embodiment, thrust bearings are mounted on both sides of the bulkhead block.

Also defined through the bulkhead 278 is a channel 314 which communicates pressure to a pressure transducer 316 coupled to the channel 314 and mounted within the upper section of the embodiment shown in FIG. 7. In the preferred embodiment this pressure transducer is of a type known to the art for detecting a pressure within the range between 0 and 5,000 p.s.i. (0 to 34.5 MPa). This is thus capable of measuring the pressure existing in the well bore as communicated to the channel 314 through the slots in the sleeve 9 and the housing 214.

Also mounted in the upper section of the embodiment shown in FIG. 7 are a plurality of means for measuring the total radial distance each of the extendible implements 242 moves in response to the motor 254 and other drive components contained in the lower section of the Preferred embodiment of the caliper tool 10. In the preferred embodiment each of these measurement means is a resistance potentiometer 318 having an actuating arm 320 coupled to a connecting rod 322 which engages a protuberant shoulder portion 324 of the respective pivot arm 242 under biasing of a spring 326 shown mounted between the body of the device 318 and a coupling/retaining collar 328. Because of this direct and continuous engagement between the coupling rod 322 and the shoulder 324, the potentiometer 318 generates an electrical signal which is proportional to the total movement of the respective pivot arm. Because there are six pivot arms in the preferred embodiment, there are also six potentiometers 318. The potentiometers 318 associated with oppositely disposed ones of the arms are paired so that the signals generated by each pair gives an indication of the total diameter or transverse dimension of the well bore defined across the respective pair of pivot arms. Each potentiometer 318 and its connecting rod 322 are mounted longitudinally in the upper section of the caliper tool 10. The protuberant shoulder 324 is shaped so that it maintains contact with the end of the rod 322 throughout the full range of radial movement of the respective pivot arm.

Although not shown in the drawings, also included in the upper section of the preferred embodiment of the caliper tool 10 is a temperature transducer of a type known in the art. For example, one having a range of up to 500°F (260°C) could be used.

The lower section of the embodiment shown in FIG. 7 has elements similar to the corresonding lower section of the embodiment shown in FIG. 6 as indicated by the use of the same reference numerals. The view shown in FIG. 7, however, is of a section of the spring guide rods 264 without showing the connecting rods 262. Also, only two of the pivot arms 242 are shown in FIG. 7 to simplify the drawing; however, each of the six arms 242 is similarly constructed to the one fully described hereinbelow. This view also shows the ball screw

coupling mechanism 270 and other features of the preferred embodiment lower section 244 not shown in FIG. 6. As (for example to the respective retaining collar 266) so that the respective potentiometer generates an electrical signal corresponding to the displacement of the respective retaining collar 266 and thus of the respective spring 268. Knowing the nature of the spring, one can use this displacement to determine the force exerted by the spring. An alternative device is a load cell 346, mounted colinearly beneath the respective spring, for generating an electrical signal proportional to the load. Use of either of these devices, or of any other suitable device by which the force exerted by each respective spring can be determined, is useful for providing information from which in situ stress measurements can be made, particularly in association with the deflection measurements taken in response to movements of the extendible arms 242. One specific measurement that can be derived is the hardness factor of the formation.

From the foregoing descriptions of the upper and lower sections of the caliper tool 10, it is readily apparent that the motor 254, the coupling rod 290, the ball screw coupling mechanism 270, the carriage 255, and the rod 264/spring 268 assemblies are combined to define the preferred embodiment of a drive means for commonly moving all six of the pivot arms 242 so that the pivoted joints 276 of the arms are simultaneously moved outwardly from the caliper tool 10 and for exerting independent forces on the pivoted arms for application to the well bore 4. This occurs when the motor 254 moves the carriage longitudinally upwardly as viewed in either FIG. 6 or FIG. 7. This movement occurs until the pin 304 of the gear 302 engages the upward direction limit switch of the limit switches 306. Oppositely, these components retract the pivoted arms 242 radially inwardly when the motor 254 drives the carriage in the longitudinally opposite direction until the pin 304 engages the downward direction limiting switch of the switches 306.

When the arms 242 are extended radially outwardly into engagement with the well bore 4, engagement with the well bore occurs through points or tips 347 connected to the ends of the sections 272 of the arms 242. In the preferred embodiment, two of the arms 242 are provided with carbide points for penetrating the formation to rigidly lock the caliper tool thereto, and the other four arms are provided with more rounded points. In the preferred embodiment it is anticipated that the holding force applied to any one of the arms can be up to 250 pounds (1100N); however, any suitable force can be designed for by using an appropriate type of compression spring as springs 268. The particular magnitude of force applied by any one spring depends on how far the respective pivot arm is extended, which depends on the size and shape of the well bore.

The final principal structural part of the preferred embodiment of the caliper tool 10 to be described is the means by which deformations of the well bore are detected. This means is contained substantially centrally within the caliper tool 10. This means is generally identified in FIG. 7 by the reference numeral 348. This includes sensor means for sensing movements of the pivot arms when the sensor means are coupled to the pivot arms. There is one such sensor means for each of the six pivot arms in the preferred embodiment. The means 348 also includes actuating means for actuating each of the sensor means after the drive means has pivoted the pivot arms 242 into engagement with the side wall of the well bore 4 so that each of the sensor means senses only movements of the pivot arms occurring after the pivot arms are pivoted into such engagement with the side wall of the well bore.

Each sensor means includes a displacement measurement means, connected to the support member defined by the upper section 240 of the caliper tool 10, for generating an electrical signal in response to movement of the respective one of the pivot arms associated with that displacement measurement means. In the preferred embodiment the displacement measurement means is a linearly variable differential transformer transducer of a suitable type known to the art, such as a Schaevitz XS-C series transducer (e.g., model 149 XS-C). This type of transducer has only a limited range of total measurable linear displacement (e.g., ±0.15 inch 3.8mm), but within that range a precision of 0.0001 inch (.0025 mm) or smaller is provided. This permits the well bore deformations (which are anticipated to be no more than approximately 0.1 inch - 2.5 mm) to be measured by the present invention with a resolution of at least 0.001 inch (.025 mm).

One of these transducers is identified by the reference numeral 350 in FIG. 7. Each transducer 350 has a body mounted longitudinally in the preferred embodiment within the housing of the upper section 240. Slidably disposed within the body is a movable member, sometimes referred to as an armature, which moves longitudinally relative to the caliper tool 10. This mounting is longitudinal in the preferred embodiment because of space limitations; however, it is contemplated that other dispositions of the transducers can be achieved if suitable transducers and tool sizes can be accommodated. When the movable member slides within the transducer body, an electrical signal is generated. When the movable member is connected to the respective arm 242, this signal is generated in

response to movement of the arm 242 brought about by deformation of the well bore 4.

This deformation sensor means also includes connecting means for releasably connecting the respective one of the pivot arms 242 to its respective transducer 350. This connecting means includes a coupling line extending from the pivot arm 242. In the preferred embodiment this coupling line is a connector strap 352 which is a long thin strip of stainless steel having one end connected in alignment with the pin or tip 347 contacting the formation at the pivot joint 276. The strap 352 extends through an engagement means, subsequently described, and around a guide shoe 354 having a curved edge 356 along which the strap extends and bends 90° so that the other end of the strap extends transversely to the first-mentioned end of the strap, which first-mentioned end extends transversely to the longitudinal direction of the caliper tool 10. The guide shoe 354 is mounted on an L-shaped bracket 355 which is connected by two Allen screws to a circular support plate 370 as shown in FIGS. 7 and 10.

This other end of the strap 352 is connected by suitable means to the carriage 255 of the drive means. In the preferred embodiment this is accomplished by a spring 358 located within the carriage 255 as shown in FIG. 7. The spring 358 has one end connected (such as by a hook and eye connection) to the strap 352 and has its other end connected to a connecting plate 360 attached to the bottom support plate 260. The spring 358 is used to eliminate slack and keep tension on the strip or strap 352 at all times in view of the difference in ratio of the two lever sections or struts that make up the extendible arm 242 and further in view of the non-linear travel ratio between the contact point of each arm and the spring drive assembly in the lower section of the caliper tool 10. This tension does not adversely affect the measuring system once the strap 352 is locked in its measuring position.

To lock the strap 352 in its measuring position, the connecting means of the deformation sensor means includes the aforementioned engagement means which is used for engaging the coupling line with the respective transducer 350 when the engagement means is in an engagement position and for disengaging the coupling line from the transducer when the engagement means is in a disengagement position. This engagement means in the preferred embodiment clamps the strap 352 to the movable member of the respective transducer 350 in response to the actuating means which in turn is responsive to the drive means. This clamp means includes an L-shaped lever or elbow member 362 having arm sections 364, 366 connected in transverse (specifically, perpendicular) relationship to each other. The arm section 364 includes a fork element 365 (see FIG. 8) having an open bifurcated end which receives and is screwed or otherwise suitably connected to a transverse extension integrally formed with the arm section 366 but forming part of the arm section 364.

This member 362 is used to accommodate the 90° change in direction between the direction of wall deflection and the direction of the travel of the movable member, or armature, of the transducer 350 when the transducer 350 is mounted longitudinally as illustrated in FIG. 7. In the preferred embodiment the elbow member 362 has a one-to-one ratio supported on a Bendix flexure spring pivot 368 secured to an L-shaped bracket 369 connected by Allen screws to the support plate 370 as shown in FIGS. 7 and 10. The plate 370 is connected by elongated members 371 as part of the framework of the upper section 240 of the caliper tool 10. This type of connection provides a spring pivot that allows precise centering of the rotation of the L-shaped lever 362 with almost no friction and hysteresis. These devices have substantially zero backlash which is of utmost importance when measuring for resolution on the order of .001 inch (.025mm), as is to be done in the preferred embodiment of the present invention. Therefore, this design and mounting of the elbow member 362 allows for automatic centering of the armature or movable member in the transducer 350 when the member 362 is disengaged from the respective arm 242. This armature is connected to the arm 366 of the lever 362 by a small thin strip 372, which is connected thereto by screws as illustrated in FIG. 7. This thin strip, which in the preferred embodiment is on the order of .004 inch (.11 mm) thick and between .187 inch (4.7mm) to .025 inch (.64mm) wide and made of stainless steel, is used so that displacement movement passes at a precise distance from this flexure pivot and so that any side load due to rotation of the L-shaped member 362 is relieved.

To lock one strap 352 to one elbow member 362 (there is one of each for each pivot arm 242) so that movement of the respective pivot arm 242 is coupled through the respective elbow member 362 to the armature of the respective transducer 350, the arm portion 364 of the elbow member 362 has a self-locking spring loaded clutch mechanism having a preferred embodiment shown in FIG. 8. The fork element 365 of the arm portion 364 is connected to the transverse extension from the arm portion 366 so that a curved surface 376 on this transverse extension lies within the central opening of the bifurcated extensions of the fork element 365. The strap 352 can be clamped to the surface 376 by a clutch roller member 378, which comprises a cylindrical sleeve 379 and a cylindrical pin

381 extending axially through and beyond both ends of the sleeve 379 as shown in FIG. 11. The member 378 is urged into frictional engagement with the strap 352 by a holding piston or anvil 380 biased towards the strap 352 by a spring 382. This construction allows a connection which communicates well bore deformation between the pin 347 engaging the formation and the armature of the transformer 350 with little or no backlash of the one-to-one ratio coupling system.

The roller 378, by means of its pin 381, has two smaller diameter ends which are received in aligned slots 383 of the fork element 365. One of these slots 383 is shown in FIG. 8. A larger diameter central cylindrical portion, defined by the sleeve 379, of the member 378 extends between the slots so that the roller 378 does not inadvertently come out of these slots.

The anvil 380 and the spring 382 are received in the central opening of the fork element 365 so that they can move longitudinally as guided by a guide rod 384 of the anvil 380. The guide rod 384 passes through a hole 385 defined through the closed end of the fork element 365. The face of the anvil 380 biased by the spring 382 towards the roller 378 is shown in FIG. 8 as having a shallow slope converging to a central area which contacts the roller 378. The slope of this convergence is kept shallow (e.g., less than approximately 13°) to make the clutch mechanism self-locking when it is released to engage the roller 378.

Movement of the roller 378 in opposition to the biasing force exerted by the spring 382 is effected by means of the actuating means which in the preferred embodiment includes a spider 386 mounted for relative movement between the support plate 370 and the respective rollers 378. Coil springs 388, one of which is shown in FIG. 10, are held between the support plate 370 and the spider 386 to bias the spider 386 towards the rollers 378. Although FIG. 10 shows a bolt 393 and a self-locking nut 395 associated with the spring 388, such nut and bolt are used for assembly but are not required to hold the plate 370 and the spider 386 together after assembly as is apparent when viewing the overall assembly in FIGS. 7 and 10. The spider 386 has a central cylindrical hub 389 from which extend radial fingers, one of which fingers is identified in FIGS. 10 and 11 by the reference numeral 390. There are six such fingers, each of which is associated with a respective one of the pivot arms 242 and the accompanying connecting assembly. Each finger 390 is bifurcated, and each bifurcation has connected to its outer end a pawl 391 having a groove for receiving the respective end of the pin 381 of the roller 378 when the springs 388 urge the pawls 391 towards their respective aligned clutches having the rollers 378. Different aspects of this construction are illustrated in FIGS. 7-11. The hub 389 has an axial channel through which the rod 290 is slidingly received.

The springs 388 bias the spider 386 towards a spider engaged position wherein each pawl 391 engages the respective roller 378 aligned therewith and moves it to its clutch disengaged position away from the respective strap 352. Thus, the cumulative force exerted by the springs 388 is greater than the cumulative force exerted by the springs 382 within the elbow members 362 in the preferred embodiment.

The spider 386 is moved in response to movement of the drive means to a spider disengaged position, wherein the pawls 391 of the spider 386 disengage from the pins 378 so that each pivot arm 242 is thereby connected to its respective transducer 350 under the engagement force exerted by the springs 382. In the preferred embodiment shown in FIG. 7, this occurs when the carriage 255 is moved sufficiently longitudinally upwardly that the shoulder 342 of the neck portion 338 engages the lower surface of the hub 389 of the spider 386 and moves the spider longitudinally upwardly. This occurs in the preferred embodiment just prior to the gearing assembly illustrated in FIG. 9 counting the twenty-two revolutions and engaging the upward direction limiting switch. Specifically, when the pivot arms 242 are fully retracted within the caliper tool 10, the shoulder 342 is spaced three inches (76mm) below the bottom surface of the hub 389. As the drive motor 254 rotates the screw shaft 292 to extend the pivot arms 242, the upper and lower sections 240, 244 move relatively towards each other and the hub 389 moves relatively towards the shoulder 342. After a sufficient length of this relative movement between the hub 389 and the shoulder 342, the shoulder enages the hub; however, this point of engagement is reached before the twenty-two revolutions of the screw shaft have been counted. Thus, the shaft continues to rotate so that the shoulder 342 pushes the spider 386 against the springs 388 towards the support plate 370. This continues for another $\frac{1}{4}$ inch (6.3mm) when the twenty-two rotation count is reached, thereby stopping further operation of the drive motor 254. This movement is related so that the pivot arms 242 are moved into engagement with the well bore before the last $\frac{1}{4}$-inch (6.3mm) linear movement of the shoulder 342. This keeps the clutches in the elbow members 362 disengaged until after the pivot arms 242 engage the well bore. A clutch disengaged position is illustrated in FIGS. 7 and 10, and a clutch engaged position is illustrated in FIG. 8.

Therefore, when the spider 386 is in its full downward position relative to the support plate 370, the pawls 391 engage the rollers 378 and hold

them at their clutch disengagement positions wherein the clamp members defined by the rollers 378 release the straps 352. When the spider 386 is in its upwardmost position relative to the support plate 370 so that the pawls 391 disengage the rollers 378, this allows the rollers 378 to be automatically biased by the springs 382 towards the straps 352 to engage them and thereby hold them adjacent the engagement surfaces 376 of the elbow members 362.

Both in summary and supplementation of the foregoing, the caliper tool 10 is used to measure the deformation of the well bore 4, such as an expansion thereof occurring in response to a fracturing process. In the preferred embodiment the diameter of the caliper tool 10 was chosen to be approximately eight inches (20.3cm) in view of the general size of well bores with which the caliper tool 10 is contemplated to be used. To adequately cover changes in the shape of the well bore, a six-arm design is used in the preferred embodiment of the caliper tool 10. The six arms 242 are uniformly spaced at 60° displacements around the central section of the caliper tool 10. The corresponding transducers 350 associated with the arms 242 are likewise arranged within the tool 10 at 60° spacings. These are located around the interior of the tool 10 so that the center is left open for the single motor 254 used in the preferred embodiment and the single main power shaft driven by the motor 254.

In the preferred embodiment of the overall tool of the present invention, the caliper tool 10 is supported by springs on each end between upper and lower packer sections. These springs are of a type which allow for approximately one to two inches (2.5 to 5.1cm) of longitudinal freedom of movement of the caliper 10 between the upper and lower packer sections. The instrument carrier section in which the caliper tool 10 is housed between the packer sections has six slots through which the arms 242 extend into contact with the formation intersected by the well bore 4. The preferred embodiment of the caliper tool 10 receives and sends electrical signals over a wireline extended through the well bore and the upper packer section into connection, via a wet connector, at the top of the caliper tool 10.

One principal feature of the preferred embodiment is that each of the arms 242 is mechanically fixed to two portions of the caliper tool to provide an increased degree of rigidity required for making the precise measurements taken with the present invention.

Another feature of the preferred embodiment is that each of the arms 242 is driven by an independent force, but from a common, single power source. This independent drive force is important because the well bores to be measured are not absolutely round so that each arm 242 will likely need to be moved a different radial distance. These differences are accommodated in the preferred embodiment by using individual compression springs on the end of each arm. This yields different force loads on each of the arms. In the preferred embodiment it is anticipated that the arms move no more than approximately 0.1 inch (2.5mm) during measurement of a formation deflection; therefore, it is desirable to exert through the springs 268 contact forces or pressures up to approximately 250 pounds of force (1100N). This is effected by appropriate selection of spring characteristics. Suitable types of springs include helical springs or Bellville spring washers.

Still another feature of the present invention is the means by which the precise measurements are obtained Although in the preferred embodiment a caliper arm may have to extend on the order of approximately two inches (5.1cm) from its fully retracted position within the caliper tool 10 to its engagement position coupling with the well bore 4, the range of precision transducers is more limited, such as between ±.015 inch (0.38mm) for full-scale deflections. This is a limitation of the linearly variable diffrential transformer 350 used in the preferred embodiment; however, this limitation is offset by the precision achieved by such a device. This transducer has a multi-coil cylindrical configuation with a central movable armature which slides longitudinally relative to the coils, thereby causing the output voltage to vary linearly with the armature displacement. No electronic amplifiers are required so that less support circuitry is needed. Furthermore, a single known type of integrated circuit chip supports these types of devices. It is contemplated that suitable transducers are currently available for use in the preferred embodiment of the present invention which requires resolving increments of .001 inch (.025mm) for ±.1 inch (2.5mm) of travel. Because such a device could not provide appropriate output over the full range of travel from the fully retracted position within the tool 10, the present invention utilizes the clutch mechanism to lock the precision measuring transducers 350 to the arms only after the arms are in their engaged position with the well bore 4 (more specifically, only after the screw shaft has rotated a predetermined number of times).

The operation of the preferred embodiment of the present invention is as follows. Power is provided through the aforementioned wireline to the caliper tool 10 after the upper and lower packers have been set and the wet connector has been attached in manners known in the art. In the preferred embodiment, the packers are locked by the locking mechanism found in the upper packer sec-

tion 8. Power for operating the motor 254 is contemplated to be provided at 60 hertz, power to the instrument section is contemplated to be at 400 hertz, and the data signals are contemplated to be sequential DC levels.

When a suitable signal is first applied to the tool 10, the motor 254 is actuated to rotate in a direction which draws the upper and lower sections 240, 244 longitudinally closer together so that the arms 242 are pivoted radially outwardly. This is accommodated in a contemplated particular embodiment by releasing an electric brake on the electric motor, actuating an alternate action relay to select the appropriate motor coil controlling the direction of rotation of the drive shaft, and bypassing a closed limit switch.

As the motor rotates its drive shaft to open the caliper arms, the gears shown in FIG. 9 rotate in correspondence to the main drive shaft. When twenty-two revolutions have occurred, the gears have been rotated so that the pin 304 engages the appropriate limit switch which deactivates the motor 254. During at least part of this maximum movement, the load is transferred to the compression springs 268 on each of the spring guide rods 264. As this load is transferred, the spring guide rods 264 move relative to the spring container carriage 255 (specifically, relative to the plates 258, 260). Sufficient movement of this carriage causes the neck portion 338 thereof to engage the spider 386. Sufficient movement of the spider 386 releases the rollers 378 so that the straps 352 are clamped to their respective transducers 350 through the interconnecting couplings.

A second control signal actuates the downhole electronics to measure or record the data obtained through the various transducers. This is performed in a manner as known to the art. To determine the amount of bore wall deflection from these data, a first reading is made when the transducers 350 are first clamped to the pivot arms 242. This provides base or "zero point" information. The fracturing fluid is then applied and another reading of the transducers 350 taken. The differences between these data and the first data are the amounts of detected movement.

When the motor controlling signal is removed from the motor 254, an electric brake on the motor locks the motor shaft to keep the drive shaft from creeping. The alternate action relay releases and resets to its next action of allowing the motor to reverse and retract the measuring arms the next time a suitable control signal is applied to the motor 254. The limiting function of the limit switch is bypassed so the electric motor will operate during its next cycle. This next application of a suitable signal causes the motor to reverse and retract the arms. A limit switch detects when the linear movement in this direction has been reached.

Once the pivot arms are retracted, another control signal is sent to again activate the downhole electronics for purposes and in a manner known in the art.

Thus, the present invention is useful for detecting movements or deformations of a well bore and thus provides information useful for determining hole orientation and fracture height. The caliper tool of this invention utilizes a single drive motor and means for exerting a respective independent force on each of several pivot arms in response to the operation of such motor. The caliper tool 10 is capable of providing precise measurements of detected deflections within a narrow range, which measurements can be taken only after the arms have been extended sufficiently and a clutch mechanism released to clamp the arms to respective precision transducers. Furthermore, this invention utilizes a free-floating construction wherein the caliper tool is mounted on springs between two interlockable packers. The caliper tool rigidly holds itself to the formation by the arms which are mechanically restrained at both ends to provide a rigid holding action with the formation.

Thus, the present invention is well adapted to carry out the objects and attain the ends and advantages mentioned above as well as those inherent therein. While preferred embodiments of the invention have been described for the purpose of this disclosure, numerous changes in the construction and arrangement of parts can be made by those skilled in the art.

Claims

1. A well bore measurement tool, comprising: a support member (278); at least one pivot arm (242) pivotally connected to said support member; and at least one sensor means (348) for sensing a movement of said pivot arm when said sensor means is coupled to said pivot arm, said sensor means including displacement measurement means (350), connected to said support member, for generating a signal in response to a sensed movement of said pivot arm; characterised in that said sensor means further includes connecting means (352) for releasably connecting said pivot aim to said displacement measurement means, and actuating means (386), connected to said support member, for actuating said connecting means to connect said pivot arm to said displacement measurement means.

2. A tool according to claim 1, wherein said connecting means includes: a connector strap (352) extending from said pivot arm; and

clamp means (378) for clamping said strap to said displacement measurement means in response to said actuating means.

3. A tool according to claim 1 or claim 2, wherein said tool further comprises drive means (254) for pivoting said pivot arm relative to said support member; and said actuating means includes clamp movement means (391), responsive to said drive means, for moving said clamp means from an engagement position, wherein said strap is clamped to said displacement measurement means, to a disengagement position, wherein said strap is unclamped from said displacement measurement means.

4. A tool according to any preceding claim, wherein said displacement measurement means includes a linearly variable differential transformer transducer (350) having a body connected to said support member and having a movable member slidably disposed for longitudinal movement within said body; said strap has a first end and a second end, said first end extending transversely to said support member and connected to said pivot arm; said connecting means further includes: a guide shoe (354) connected to said support member, said guide shoe having a curved edge along which said strap extends so that said second end of said strap extends transversely to said first end of said strap; and means (358) for connecting said second end of said strap to said drive means; and said clamp means includes: an elbow member (362) having a first arm section (366) and a second arm section (364) connected in transverse relationship to each other, said first arm section having an engagement surface (376) and having a clamp member (378) biased towards said engagement surface but responsive to said clamp movement means, said strap disposed between said engagement surface and said clamp member so that said clamp member holds said strap against said engagement surface when said clamp movement means releases said clamp member for movement to said engagement position and so that said clamp member releases said strap when said clamp movement means holds said clamp member in said disengagement position, and said second arm section connected to said movable member of said transducer; and means (368) for pivotably connecting said elbow member to said support member.

5. A tool according to claim 3, further comprising means (344, 346), connected to said support member, for generating a signal corresponding to the force exerted by said drive means on said pivot arm.

6. A tool according to any preceding claim further comprising means (318), connected to said support member, for generating a signal corresponding to the total radial movement of said pivot arm.

7. A tool according to claim 1, comprising: a plurality of pivot arms (242), each of said arms including a first section (272) having a first end pivotally connected to said support member and having a second end, and each of said arms further including a second section (274) having a first end pivotally connected to said second end of said first section and having a second end; drive means (254), connected to said support member and connected to said second ends of said second sections of said pivot arms, for commonly moving said pivot arms so that said second ends of said first sections and said first ends of said second sections are simultaneously moved outwardly from said support member and for exerting independent forces on said pivot arms, said drive means including a carriage (255); a plurality of spring guide rods (262) slidably disposed in said carriage, each of said rods connected to the second end of the second section of a respective one of said pivot arms; a plurality of springs (268), each of said springs mounted on a respective one of said rods; and means (290), connected to said support member and said carriage, for moving said carriage relative to said support member; and a plurality of sensor means (348) for sensing movements of said pivot arms, each of said sensor means associated with a respective one of said plurality of pivot arms; said displacement measurement means (350) comprising transducer means for converting a sensed movement of the respective one of said pivot arms into a corresponding electrical signal; said connecting means (352) comprising a coupling line extending from the respective one of said pivot arms; and said actuating means (386) comprising engagement means for engaging said coupling line with said transducer means when said engagement means is in an engagement position and for disengaging said coupling line from said transducer means when engagement means is in a disengagement position; and means (342), responsive to movement of said carriage , for moving said engagement means between said engagement and disengagement positions.

8. A tool according to claim 7, wherein said carriage has longitudinally spaced first (258) and second ends (260), said first end of said carriage being disposed nearer than said second end of said carriage to said pivot arms and said second ends of said carriage having longitudinally aligned apertures defined therethrough, each pair of said aligned apertures slidingly receiving a respective one of said rods; and said drive means further includes: seal means (334, 336), disposed in each of said apertures, for providing balanced pressure seals between said carriage and said rods; and a plurality of retaining collars (266), each of said collars disposed on a respective one of said rods between said first and second ends of said carriage so that the respective one of said springs mounted on the respective one of said rods extends between the respective one of said collars and said second end of said carriage.

9. A tool according to claim 7 or claim 8, wherein said means for moving said carriage within said housing includes a single electric motor (254); and coupling means (290, 292) for coupling said motor to said carriage.

10. A tool according to any of claims 7 to 9, further comprising sensor means (344, 346), connected to said support member, for generating respective electrical signals corresponding to the forces exerted by each of said plurality of springs.

Patentansprüche

1. Ein Bohrlochmeßgerät, bestehend aus: einem Stützteil (278); mindestens einem Gelenkarm (242), schwenkbar mit besagtem Stützteil verbunden und wenigstens einer Sensoreinrichtung (348) zum Erkennen einer Bewegung besagten Gelenkarms, wenn besagte Sensoreinrichtung mit besagtem Gelenkarm verbunden ist, wobei besagte Sensoreinrichtung eine Verdrängungsmeßeinrichtung (350) beinhaltet, die mit besagtem Stützteil verbunden ist und dem Erzeugen eines Signals infolge einer festgestellten Bewegung besagten Gelenkarms dient; dadurch gekennzeichnet, daß besagte Sensoreinrichtung weiterhin eine Verbindungseinrichtung (352) zum lösbaren Verbinden besagten Gelenkarms mit besagter Verdrängungsmeßeinrichtung und eine Betätigungseinrichtung (386) vorsieht, die mit besagtem Stützteil verbunden ist und einer Betätigung besagter Verbindungseinrichtung in Kontakt mit besagtem Gelenkarm und besagter Verdrängungsmeßeinrichtung dient.

2. Ein Gerät nach Anspruch 1, wobei besagte Verbindungseinrichtung aus einem Verbindungsband (352), das sich von besagtem Gelenkarm ausdehnt und einer Klemmeinrichtung (378) zum Verklemmen besagten Bandes mit besagter Verdrängungsmeßeinrichtung als Reaktion auf besagte Betätigungseinrichtung besteht.

3. Ein Werkzeug nach einem der Ansprüche 1 oder 2, wobei besagtes Werkzeug weiter aus einer Antriebseinrichtung (254) zum Schwenken besagten Gelenkarms, relativ zum besagten Stützteil besteht und besagte Betätigungseinrichtung eine Klemmenbewegungseinrichtung (391) vorsieht, die auf besagte Antriebseinrichtung reagiert und dem Bewegen besagter Klemmeinrichtung aus einer Eingriffsstellung, in der besagtes Band mit besagter Verdrängungsmeßeinrichtung verklemmt ist, in eine ausgekuppelte Stellung dient, in der besagtes Band von besagter Verdrängungsmeßeinrichtung befreit ist.

4. Ein Werkzeug nach mindestens einem der o.g. Ansprüche, wobei die Verdrängungsmeßeinrichtung einen linear variablen Differenztransformator-Meßwandler (350) umfaßt, dessen Körper mit besagtem Stützteil verbunden ist und ein bewegliches Teil vorsieht, das gleitend in besagtem Körper für Längsbewegungen ausgeführt ist; besagtes Band hat ein erstes Ende und ein zweites Ende. Das erste Ende verläuft quer zum besagten Stützteil und ist mit besagtem Gelenkarm verbunden; besagte Verbindungseinrichtung umfaßt weiterhin: einen Führungsschuh (354), der mit besagtem Stützteil verbunden ist, wobei besagter Führungsschuh einen gebogenen Rand aufweist, an dem besagtes Band so verläuft, daß sich besagtes zweites Ende besagten Bandes quer zum ersten Ende besagten Bandes ausdehnt; sowie einer Einrichtung (358) zum Verbinden besagten zweiten Endes besagten Bandes an besagter Antriebseinrichtung, während sich besagte Klemmeinrichtung weiterhin aus einem Krümmerteil (362) mit einem ersten Armbereich (366) und einem zweiten Armbereich (364), die quer zueinander verbunden sind, wobei besagter erster Armbereich eine Eingriffsfläche (376) und ein Klemmteil (378) aufweist, das in Richtung besagter Eingriffsfläche vorgespannt ist, jedoch auf besagte Klemmenbewegungseinrichtung anspricht, wobei besagtes Band zwischen besagter Eingriffsfläche und besagtem Klemmteil so ausgeführt ist, daß be-

sagtes Klemmteil besagtes Band gegen besagte Eingriffsfläche hält, wenn besagte Klemmenbewegungseinrichtung besagtes Klemmteil zum Bewegen besagten Bandes löst, wenn besagte Klemmenbewegungseinrichtung besagtes Klemmteil in besagter ausgekuppelter Stellung hält sowie aus einem besagten zweiten Armbereich, der mit besagtem beweglichen Teil besagten Meßwandlers verbunden ist; sowie eine Einrichtung (368) zum schwenkbaren Verbinden besagten Krümmers mit besagtem Stützteil zusammensetzt.

5. Ein Werkzeug nach Anspruch 3, das sich weiterhin aus einer Einrichtung (344, 346) zusammensetzt, die mit besagtem Stützteil verbunden ist und dem Erzeugen eines Signals im Verhältnis zur Kraft dient, die durch besagte Antriebseinrichtung auf besagten Gelenkarm ausgeübt wird.

6. Ein Werkzeug nach wenigsten einen der o.g. Ansprüche, das sich weiter aus einer Einrichtung (318) zusammensetzt, die mit besagtem Stützteil verbunden ist und dem Erzeugen eines Signals dient, daß der totalen Radialbewegung besagten Gelenkarms entspricht.

7. Ein Werkzeug nach Anspruch 1, bestehend aus: einer Mehrzahl von Gelenkarmen (242), dessen jeder besagte Arm einen ersten Bereich (272) vorsieht, wovon ein erstes Ende schwenkbar mit besagtem Stützteil verbunden ist und ein zweites Ende vorsieht, wobei jeder besagter Arm weiterhin einen zweiten Bereich (274), dessen erstes Ende schwenkbar mit besagtem zweiten Ende des ersten Bereichs verbunden ist und ein zweites Ende vorsieht; einer Antriebseinrichtung (254), die mit besagtem Stützteil und besagten zweiten Enden besagter zweiter Bereiche besagter Gelenkarme verbunden ist und dem gemeinsamen Bewegen besagter Gelenkarme so dient, daß besagte zweite Ende besagter erster Bereiche und besagte erste Enden besagter zweiter Bereiche gleichzeitig vom besagten Stützteil nach außen bewegt werden und unabhängige Kräfte auf besagte Gelenkarme ausüben, wobei besagte Antriebseinheit weiter aus einem Läufer (255), einer Mehrzahl von Federführungsstangen (262), die gleitend in besagtem Läufer ausgeführt sind besteht, wobei jede der besagten Stangen mit dem zweiten Ende des zweiten Bereichs jeweils eines der besagten Gelenkarme verbunden ist; einer Mehrzahl von Federn (268), die jeweils auf einer der besagten Stangen montiert ist; einer Einrichtung (290), die mit besagtem Stützteil und besagtem Läufer verbunden ist, mit der besagter Läufer, relativ zu besagtem Stützteil, bewegt wird; und einer Mehrzahl von Sensoreinrichtungen (348) zum Erkennen von Bewegungen besagter Gelenkarme, wobei jede der besagten Sensoreinrichtungen jeweils einem der besagten Mehrzahl von Gelenkarmen zugehört und besagte Verdrängungsmeßeinrichtung (350) aus einer Meßwandlereinrichtung zum Umwandeln einer erkannten Bewegung jeweils einer der besagten Gelenkarme in ein entsprechendes Stromsignal besteht; wobei besagte Verbindungseinrichtung (352) aus einer Kupplungsleitung besteht, die sich von jeweils einem der besagten Gelenkarme ausdehnt und besagte Betätigungseinrichtung (386), bestehend aus einer Eingriffseinrichtung zum Eingriff besagter Kupplungsleitung in besagte Meßwandlereinrichtung, wenn sich besagte Eingriffseinrichtung in der Eingriffsstellung befindet und zum Auskuppeln besagter Kupplungsleitung aus besagter Meßwandlereinrichtung, wenn sich die Eingriffseinrichtung in der ausgekuppelten Stellung befindet; sowie einer Einrichtung (342), die auf Bewegungen besagten Läufers anspricht, womit besagte Eingriffseinrichtung zwischen besagten Eingriffs- und Auskupplungsstellungen bewegt wird.

8. Ein Werkzeug nach Anspruch 7, wobei besagter Läufer längs im Abstand befindliche erste Enden (258) und zweite Enden (260) vorsieht, wobei besagtes erstes Ende besagten Läufers näher als das zweite Ende besagten Läufers an besagten Gelenkarmen ausgeführt ist und zweite Enden besagten Läufers längs abgestimmte, durchgehende Öffnungen aufweisen, wobei jedes Paar abgestimmter Öffnungen jeweils einer der besagten Stangen gleitend aufnimmt; und besagte Antriebseinrichtung weiter aus Dichteinrichtungen (334, 336), die in jeder der besagten Öffnungen ausgeführt sind, durch die eine ausgeglichene Druckdichtung zwischen besagtem Läufer und besagten Stangen realisiert wird; sowie mehreren Befestigungskränzen (266) besteht, wobei jeder der besagten Kränze auf jeweils einem der besagten Stangen zwischen dem ersten und den zweiten Enden besagten Läufers so ausgeführt ist, daß sich die jeweilige der besagten Federn, die auf den jeweiligen der besagten Stangen aufgezogen sind, zwischen dem jeweils zutreffenden der besagten Kränze und besagten zweiten Ende besagten Läufers ausdehnen.

9. Ein Werkzeug nach Anspruch 7 oder 8, wobei besagte Einrichtung zum Bewegen besagten Läufers in besagtem Gehäuse einen Elektro-

motor (254) und die Kupplungseinrichtungen (290, 292) zum Verbinden besagten Motors mit besagtem Läufer vorsieht.

10. Ein Werkzeug nach wenigstens einem der Ansprüche 1 bis 9, das weiterhin aus einer Sensoreinrichtung (344, 346) besteht, die mit besagtem Stützteil zum Erzeugen von Stromsignalen verbunden ist, die den Kräften entsprechen, die von jeder der besagten Mehrzahl von Federn ausgeübt wird.

Revendications

1. Un appareil de mesure de puits de forage comprenant les éléments suivants: un support (278); au minimum un bras de pivotement (242) relié de façon pivotante à ce support; et au minimum un capteur (34) détectant les mouvements de ce bras de pivotement lorsque ce capteur est couplé avec le bras de pivotement, ce capteur étant muni d'un dispositif de mesure des déplacements (350), relié au support, pour la production d'un signal en réponse à un mouvement détecté du bras de pitovement susmentionné; l'appareil de mesure est caractérisé par le fait que ce capteur comprend, en plus, un dispositif de raccordement (352) pour raccorder en mode décrochable le bras de pivotement à l'appareil de mesure du déplacement ci-dessus, et un dispositif de commande (386), relié au support, et commandant le dispositif de raccordement pour raccorder le bras de pivotement à l'appareil de mesure déplacement susmentionné.

2. Un appareil conforme à la renvendication 1 dans lequel le dispositif de raccordement comprend une courroie de raccordement (352), partant du bras de pivotement susmentionné, et un dispositif de serrage (378) pour serrer ladite courroie contre l'appareil de mesure du déplacement en réponse au dispositif de commande.

3. Un appareil conforme à la renvendication 1 ou 2 comprenant également un dispositif d'entraînement (254) pour faire pivoter le bras de pivotement autour du membre, ce dispositif de commande disposant d'un appareil de déplacement (391) du dispositif de serrage, dépendant du dispositif d'entraînement, pour assurer le déplacement du dispositif de serrage d'une position d'engagement, dans laquelle la courroie est attachée sur le dispositif de mesure des déplacements, dans une position dégagée dans laquelle la courroie est detachée du dispositif de mesure des déplacements.

4. Un appareil conforme à une des renvendications ci-dessus dans lequel ce dispositif de mesure des déplacements comprend un transformateur différentiel linéaire variable (350) dont le corps est connecté au support et comprenant un élément coulissant pour les déplacements longitudinaux au sein du corps; cette courroie possède un premier et un deuxième bout, le premier joignant transversalement le support et étant relié au bras de pivotement; ce dispositif de connexion comprend également un sabot de guidage (354), relié au support, ce sabot de guidage possédant un bord arrondi longé par la courroie, de sorte que le deuxième bout de la courroie soit transversal par rapport au premier bout de ladite courroie; et un dispositif (358) de raccordement du deuxième bout de ladite courroie au dispositif d'entraînement susmentionné; l'attache comprend un coude (362) avec un premier bras (366) et un deuxième bras (364) transversales l'une par rapport à l'autre, le premier bras possédant une surface de prise (376) et un élément de fixation (378) incliné vers la surface de prise mais sensible au mouvement de la fixation, cette courroie étant placée entre la surface de prise et l'élément de fixation afin que ce dernier d'une part tienne la courroie contre la surface de prise, lorsque le mouvement de fixation dégage l'élément de fixation pour qu'il se déplace vers sa position d'engagement susmentionnée, d'autre part dégage la courroie lorsque le dispositif de déplacement de la fixation tient l'élément de fixation dans sa position libre, et le deuxième bras étant relié à l'élément mobile du capteur; et un dispositif (368) de raccordement pivotant du coude et du support.

5. Un appareil conforme à la renvendication 3 et comprenant également un dispositif (344,346) relié au support susmentionné et produisant un signal correspondant à la force exercée par le dispositif d'entraînement susmentionné sur le bras de pivotement ci-dessus.

6. Un appareil conforme à toute revendication précédente comprenant également un dispositif (318) relié au support, pour la production d'un signal correspondant au déplacement radial total du bras de pivotement.

7. Un appareil conforme à la renvendication 1 comprenant: plusieurs bras de pivotement (242) chacun desquels comprend une première section (272) avec un premier bout relié par pivotement au support et un deuxième bout; chacun de ces arbres comprend également

une deuxième section (274) avec un premier bout relié par pivotement au deuxième bout de la première section, et un deuxième bout; un dispositif d'entraînement (254) relié au support ainsi qu'aux deuxième bouts des deuxième sections des bras de pivotement pour déplacer conjointement les bras de pivotement de sorte que les deuxièmes extrémités desdites premières sections et les premières extrémités des deuxièmes sections soient déplacées simultanément vers l'extérieur à partir du support, ce dispositif d'entraînement comprenant un chariot (255), plusieurs tiges de guidage à ressort (262), coulissant dans le chariot et chacune étant reliée à la deuxième extrémité de la deuxième section d'un des bras de pivotement correspondants; plusieurs ressorts (268), chacun desquels est monté sur une tige correspondante; et un dispositif (290) relié au support et au chariot et servant à déplacer le chariot en fonction du support; et plusieurs capteurs (348) pour détecter les déplacements des bras de pivotement susmentionnés, chacun de ces capteurs correspondant à son bras de pivotement; le dispositif de mesure des déplacements (350) comprend un capteur pour convertir un mouvement détecté du bras de pivotement respectif en signal électrique correspondant; le dispositif de raccordement 352 comprend une ligne d'accouplement qui part du bras de pivotement respectif; et le dispositif de commande (386) comprenant un dispositif d'entraînement assurant la mise en prise de la ligne d'accouplement avec le capteur, lorsque ce dispositif d'entraînement se trouve dans sa position de mise en place, et le dégagement de la ligne d'accouplement du capteur lorsque le dispositif de mise en prise se trouve dans la position de désengagement; et un dispositif (342) dépendant du mouvement du chariot et assurant le déplacement du dispositif d'entraînement ci-dessus entre ses positions d'entraînement et de dégagement.

8. Un appareil conforme à la revendication 7 dans lequel le chariot possède une première (258) et une deuxième (260) extrémités espacés longitudinalement, la première extrémité du chariot étant plus rapprochée des bras de pivotement que la deuxième extrémité du chariot et les deuxièmes extrémités du chariot possédant des ouvertures alignées longitudinalement qui les traversent, chaque paire de ces ouvertures alignées recevant une des tiges correspondantes coulisse; en outre, ce dispositif d'entraînement comprend également une garniture d'étanchéité (334, 336), placée dans chacune de ces ouvertures et assurant une étanchéité à pression équilibrée entre le chariot et les tiges; et plusieurs colliers de fixation (266) disposés sur une de ces tiges, entre la première et la deuxième extrémité de ce chariot, de sorte que l'extrémité correspondante d'un des ressorts monté sur la tige correspondante s'introduise entre son collier correspondant et la deuxième extrémité du chariot.

9. Un appareil conforme à la revendication 7 ou à la revendication 8 dans lequel le dispositif de déplacement du chariot dans le logement comprend un moteur électrique unique (254), et un raccord (290, 292) pour accoupler le moteur au chariot ci-dessus.

10. Un appareil conforme aux revendications 7 à 9 comprenant également un capteur (344, 346) relié au support, pour la production de signaux électriques correspondant aux forces appliquées par chacun des ressorts susmentionnés.

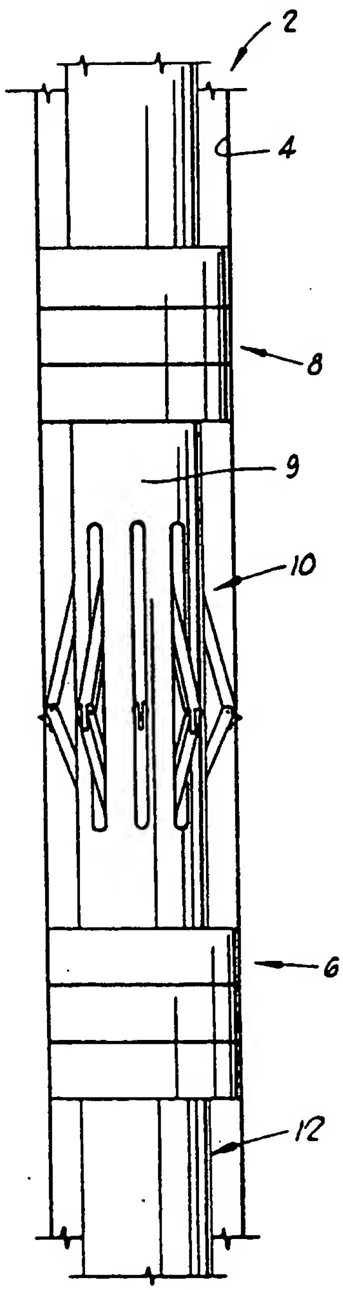

FIG. 1

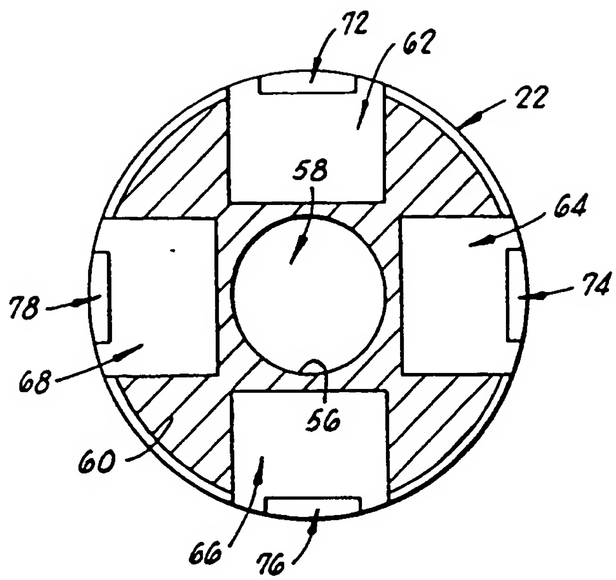

FIG. 3

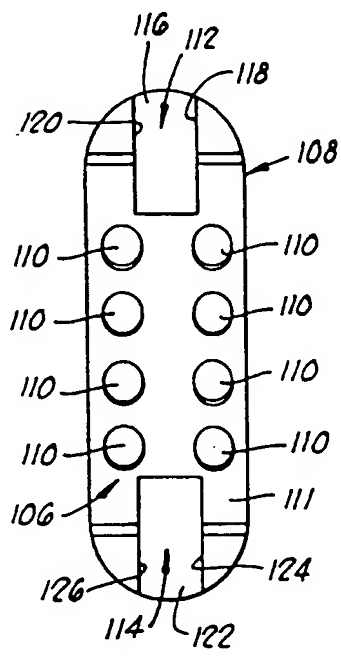

FIG. 4

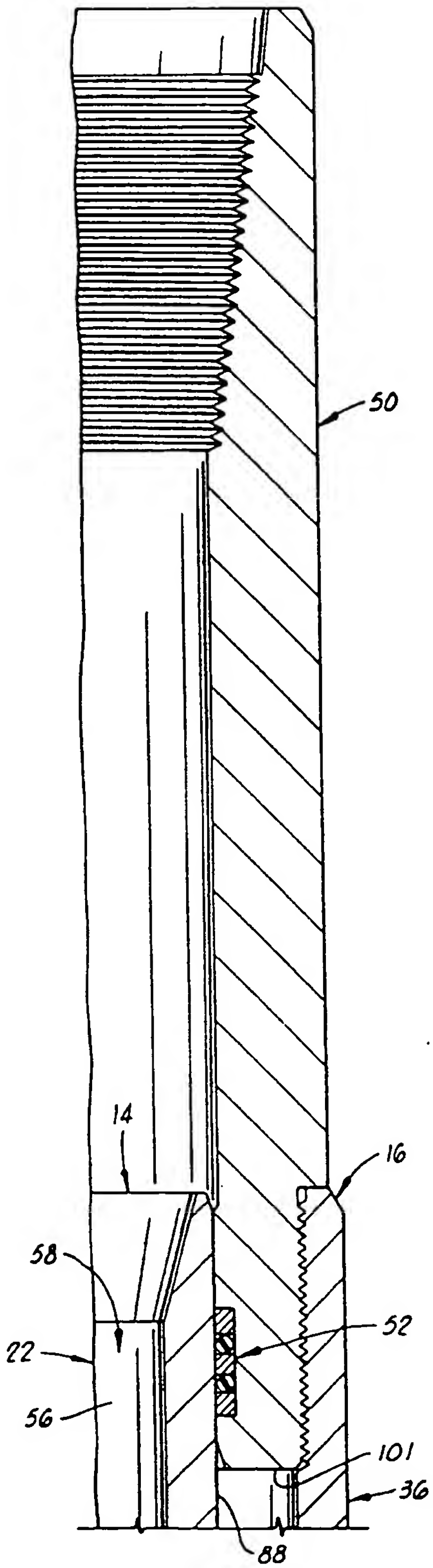
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FIG. 2A

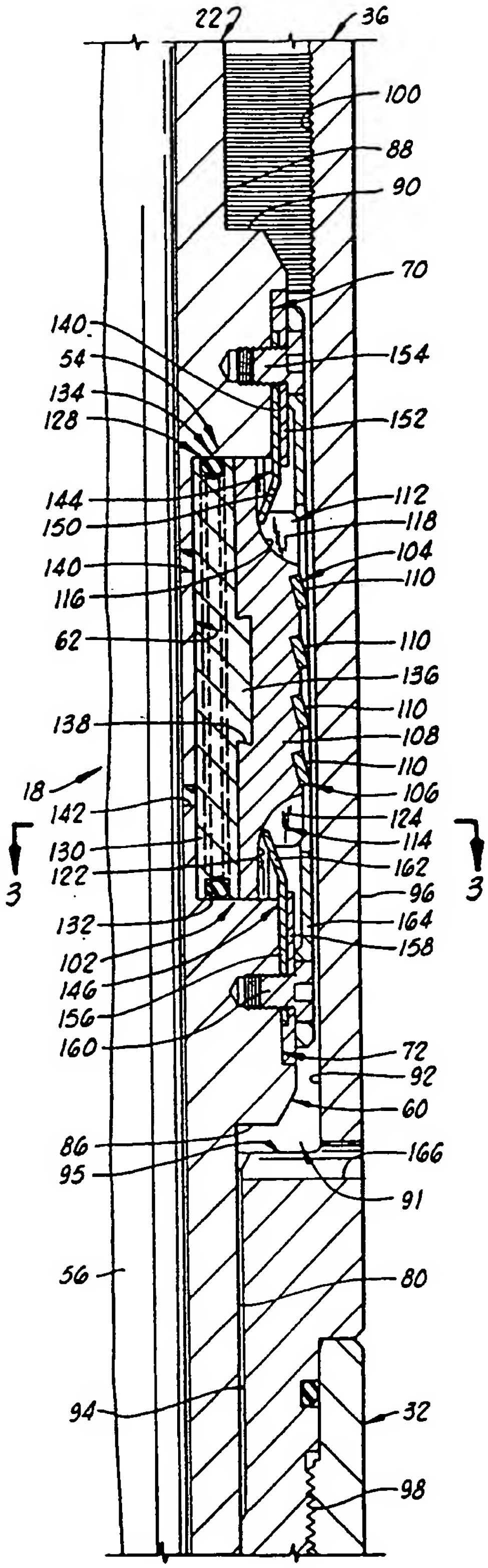
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FIG. 2B

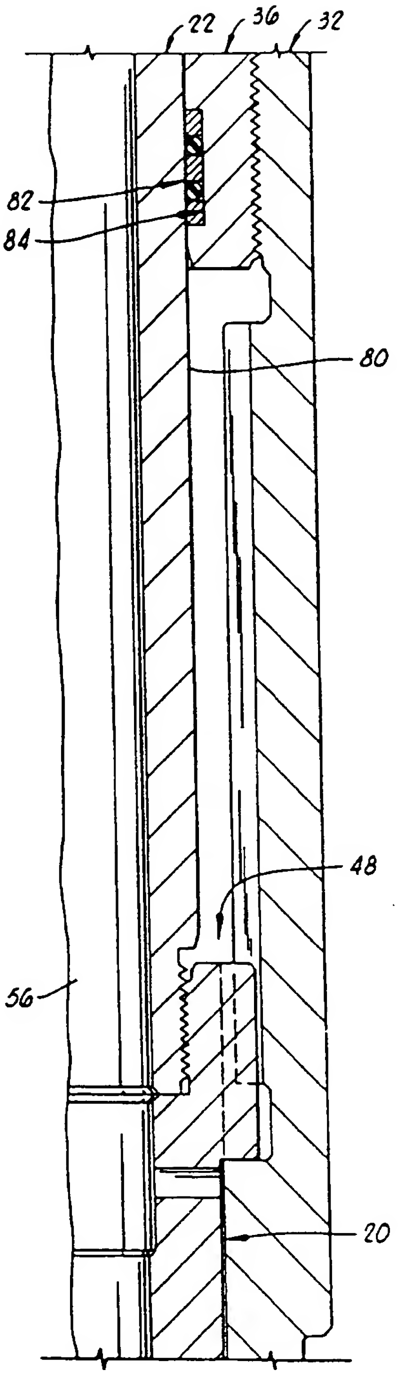

FIG. 2C

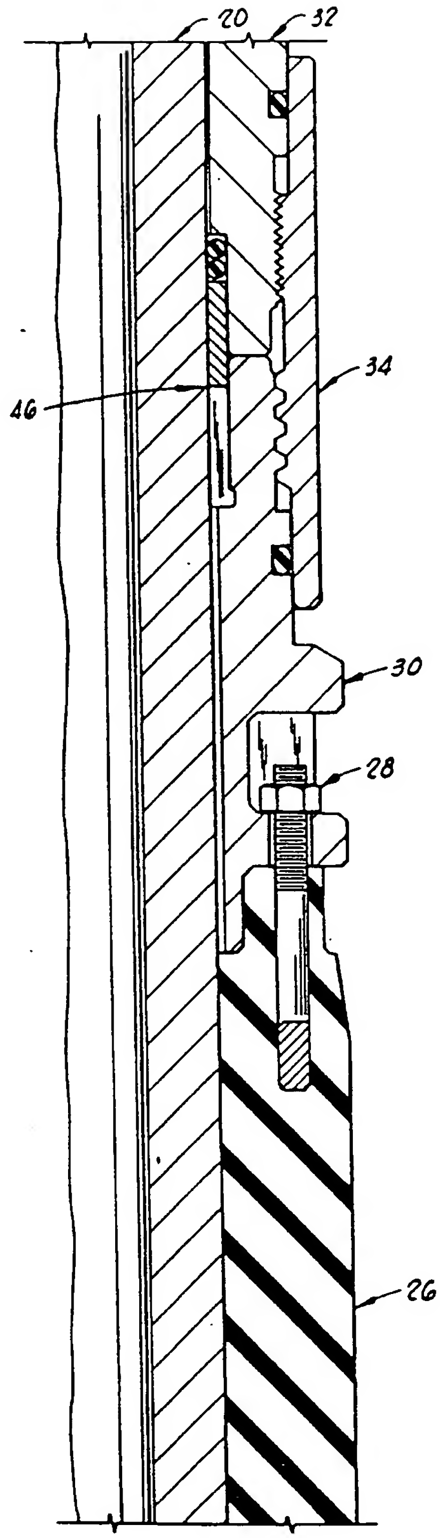

FIG. 2D

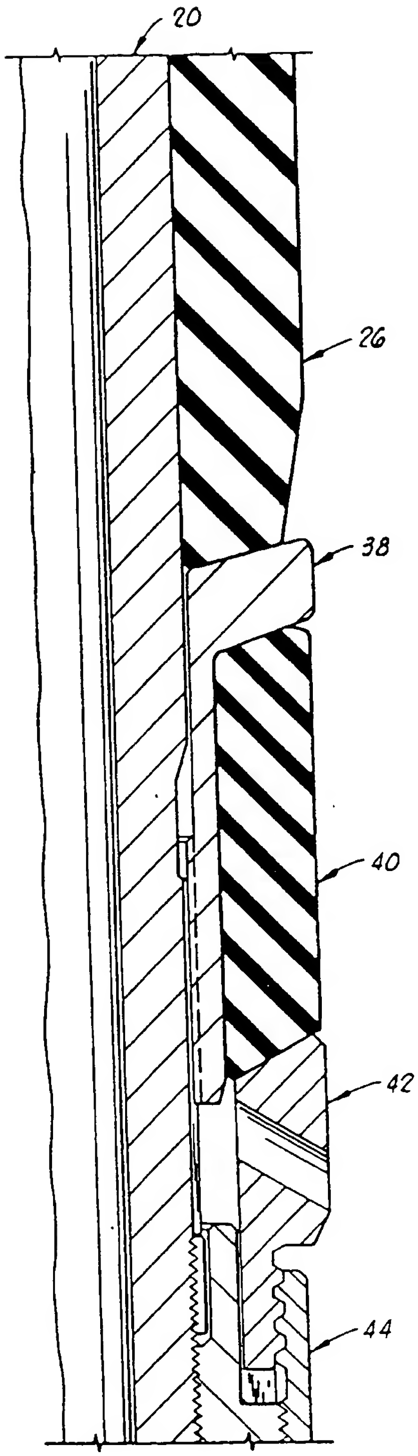

FIG. 2E

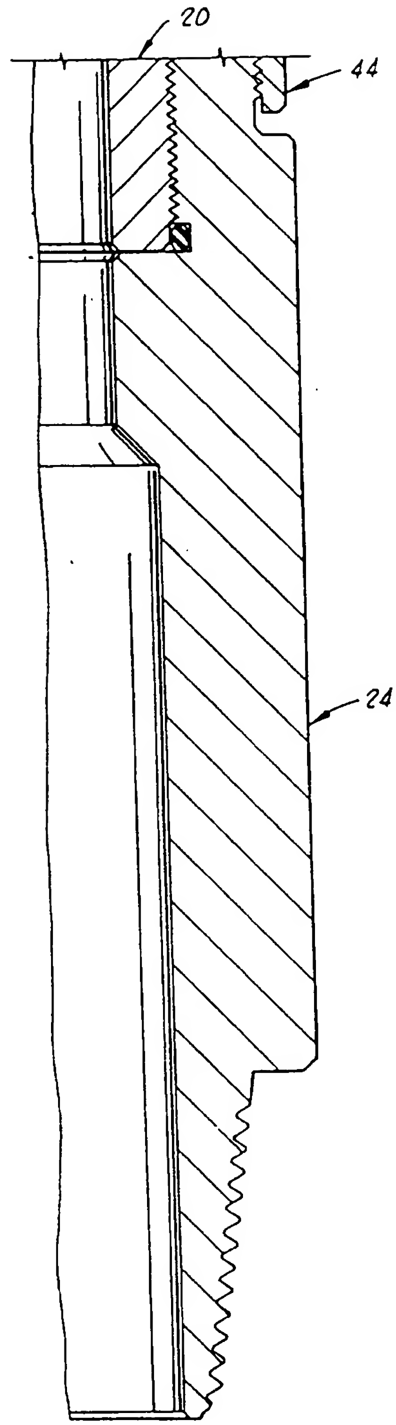

FIG. 2F

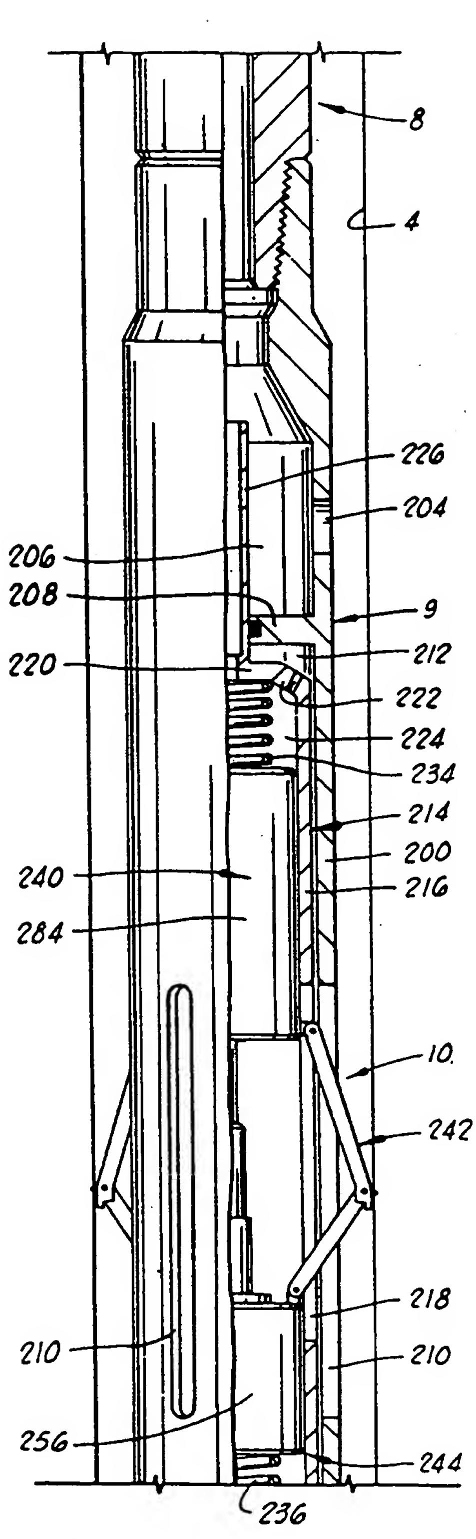
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FIG. 5A

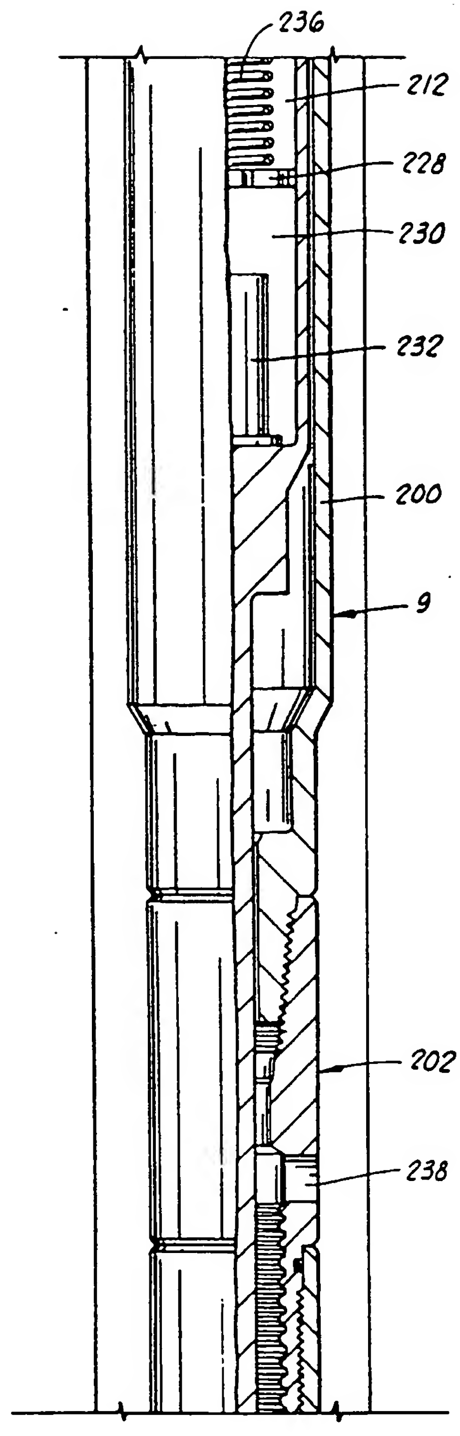
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FIG. 5B

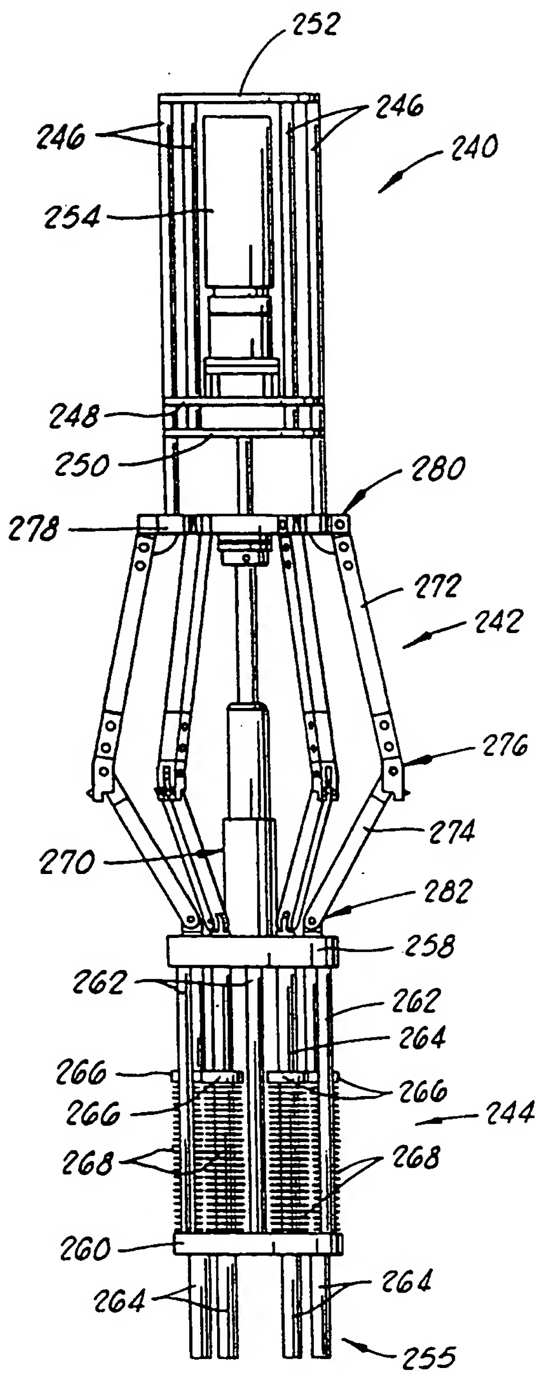
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FIG. 6

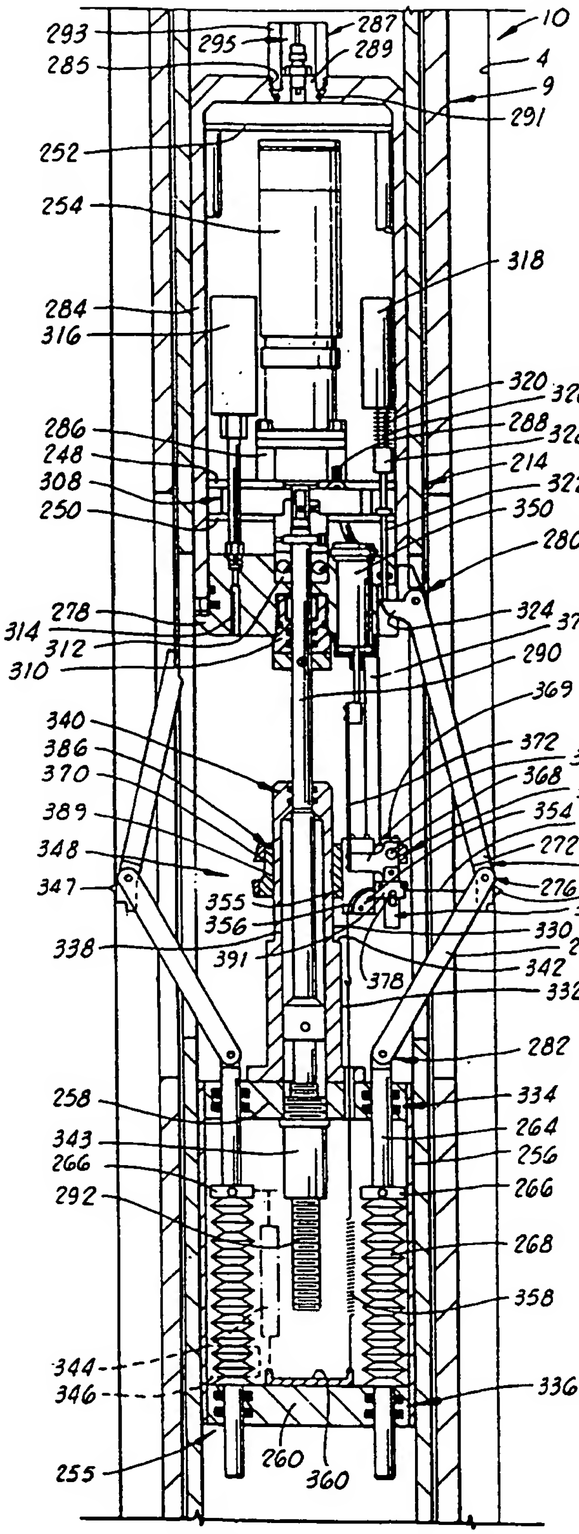

FIG. 7

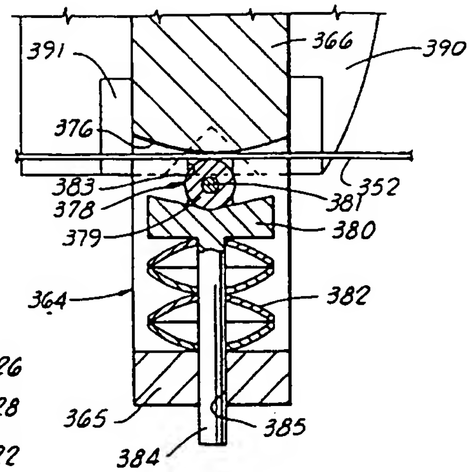

FIG. 8

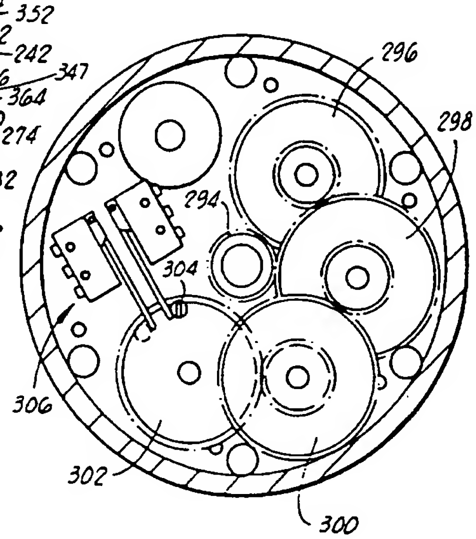

FIG. 9

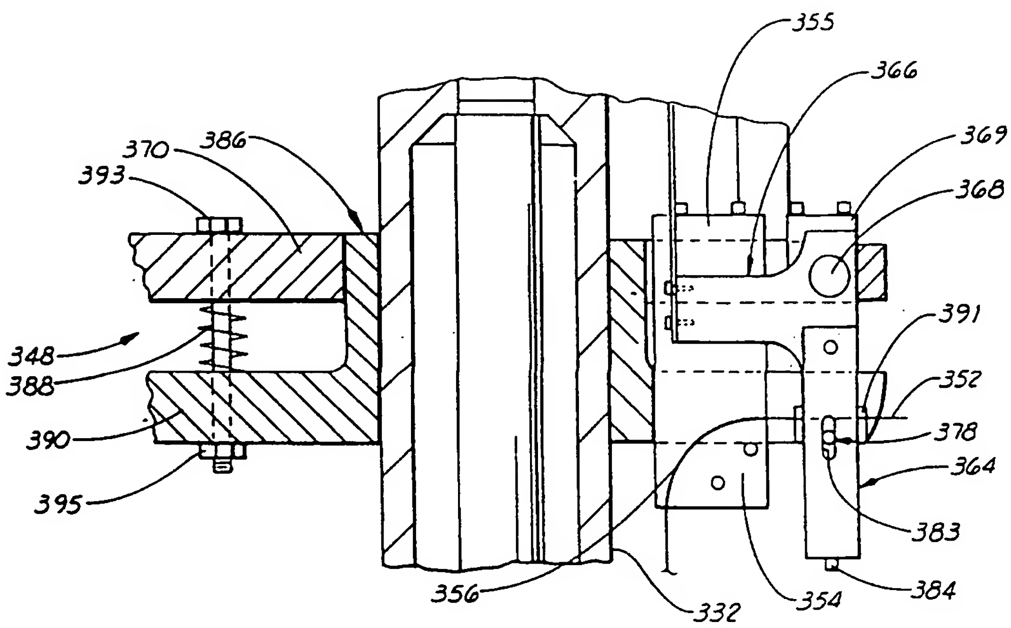
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FIG. 10

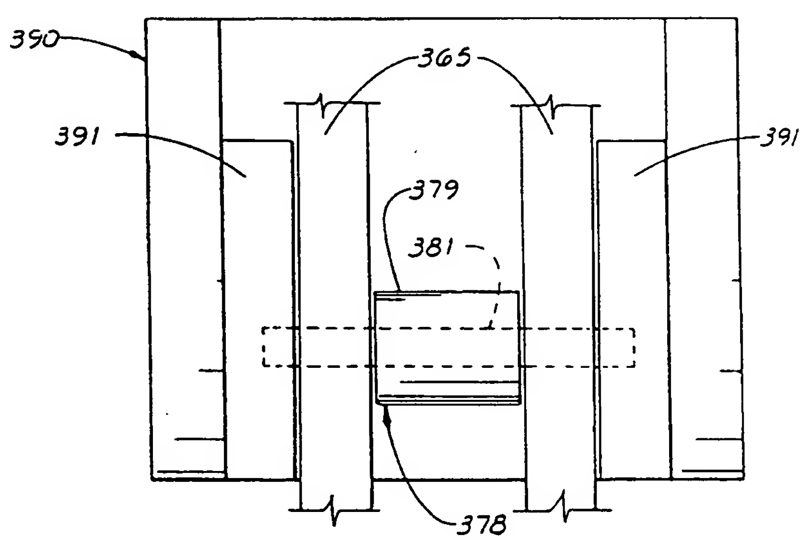
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FIG. 11